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Hahn et al.

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(45) **Date of Patent: Aug. 7, 2012**

(54) **HANDLE FOR POWER TOOL**

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(73) Assignee: **Black & Decker Inc.**, Newark, DE (US)

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(22) Filed: **Jan. 23, 2009**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Jan. 24, 2008 (GB) 0801313.8

(51) **Int. Cl.**
B25G 1/10 (2006.01)

(52) **U.S. Cl.** **16/431**; 173/162.2

(58) **Field of Classification Search** 16/422, 16/426, 430, 110.1, 446, 431; 81/489; 173/210, 173/162.1, 162.2
See application file for complete search history.

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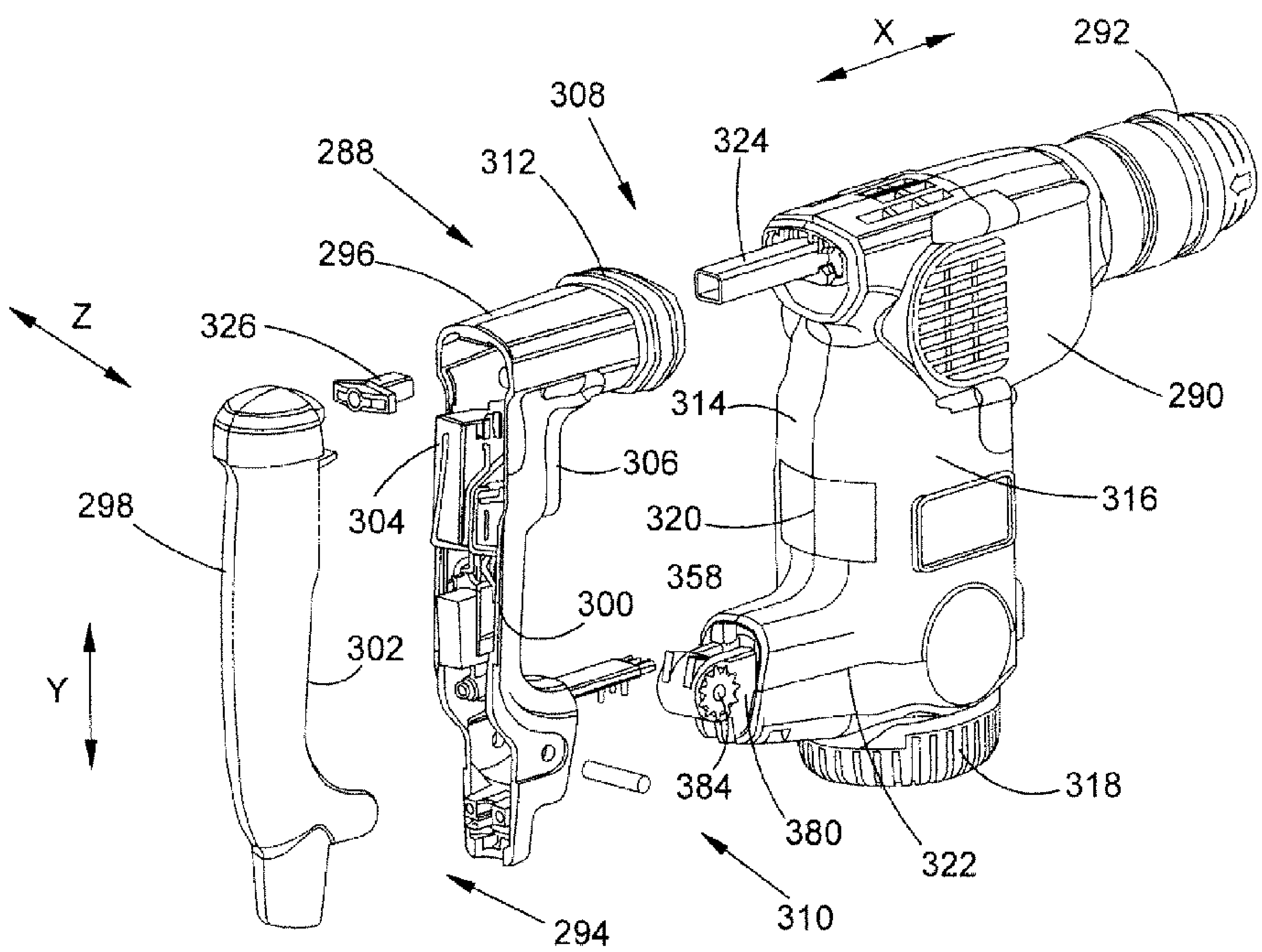
Primary Examiner — William L. Miller
(74) *Attorney, Agent, or Firm* — Kofi Schulterbrandt; Scott B. Markow; Adan Ayala

(57) **ABSTRACT**

A handle housing for a handle for a power tool, the handle housing having a first housing part; and a second housing part adapted to be mounted to the first housing part and subjected to a bending stress when mounted to said first housing part, the said first and second housing parts defining a chamber for accommodating one or more components of the power tool.

2 Claims, 26 Drawing Sheets



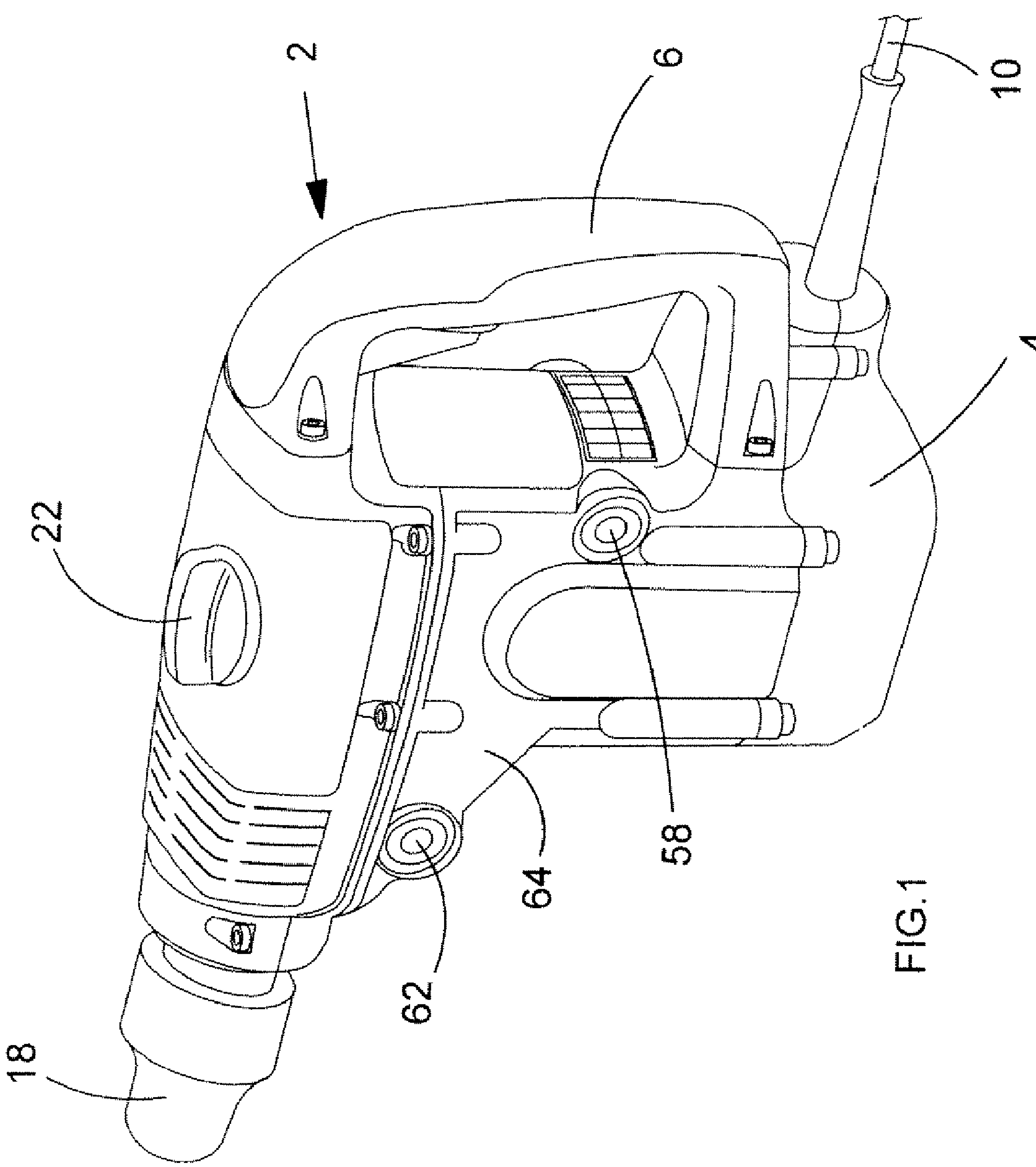


FIG.1

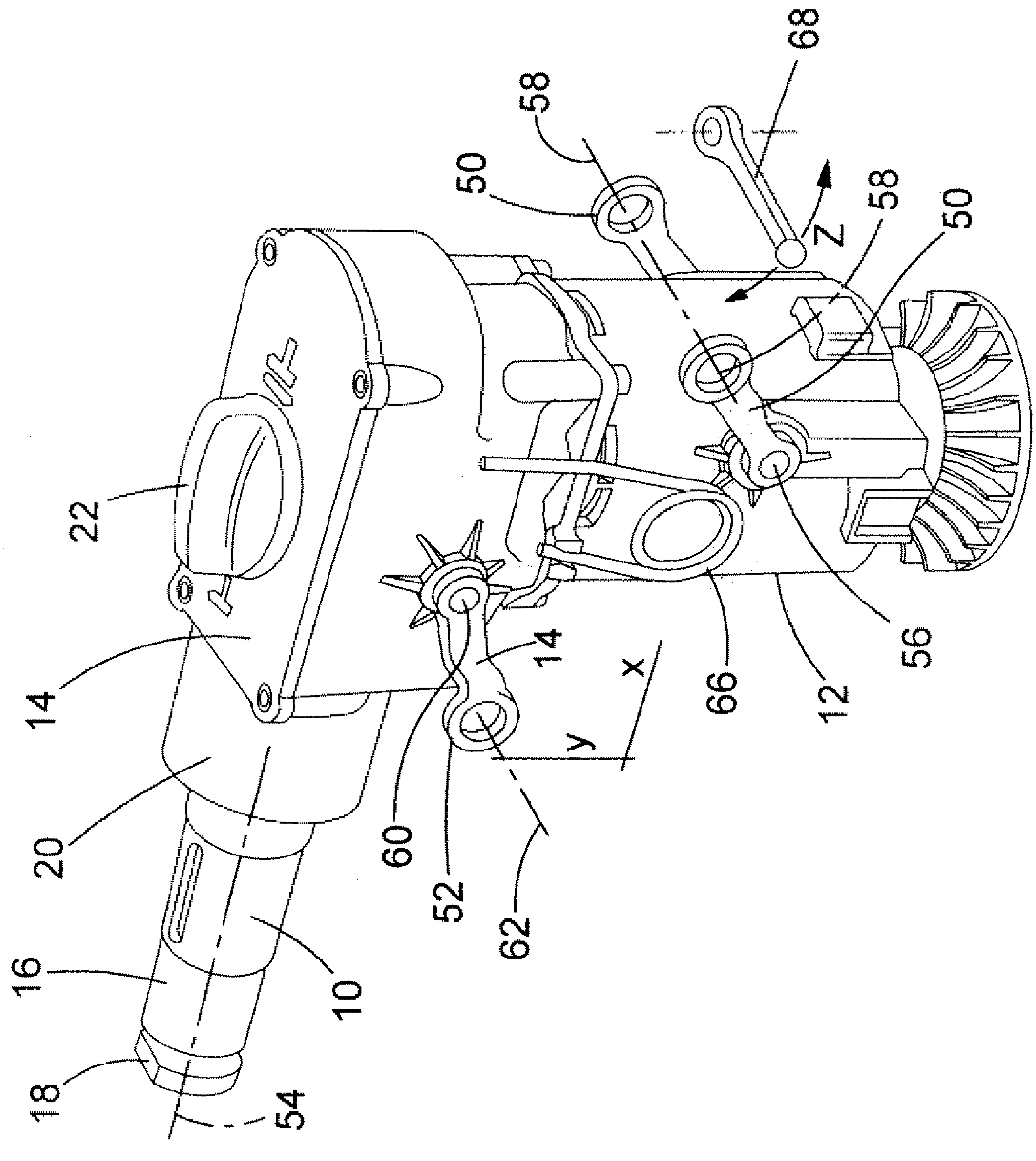


FIG.2

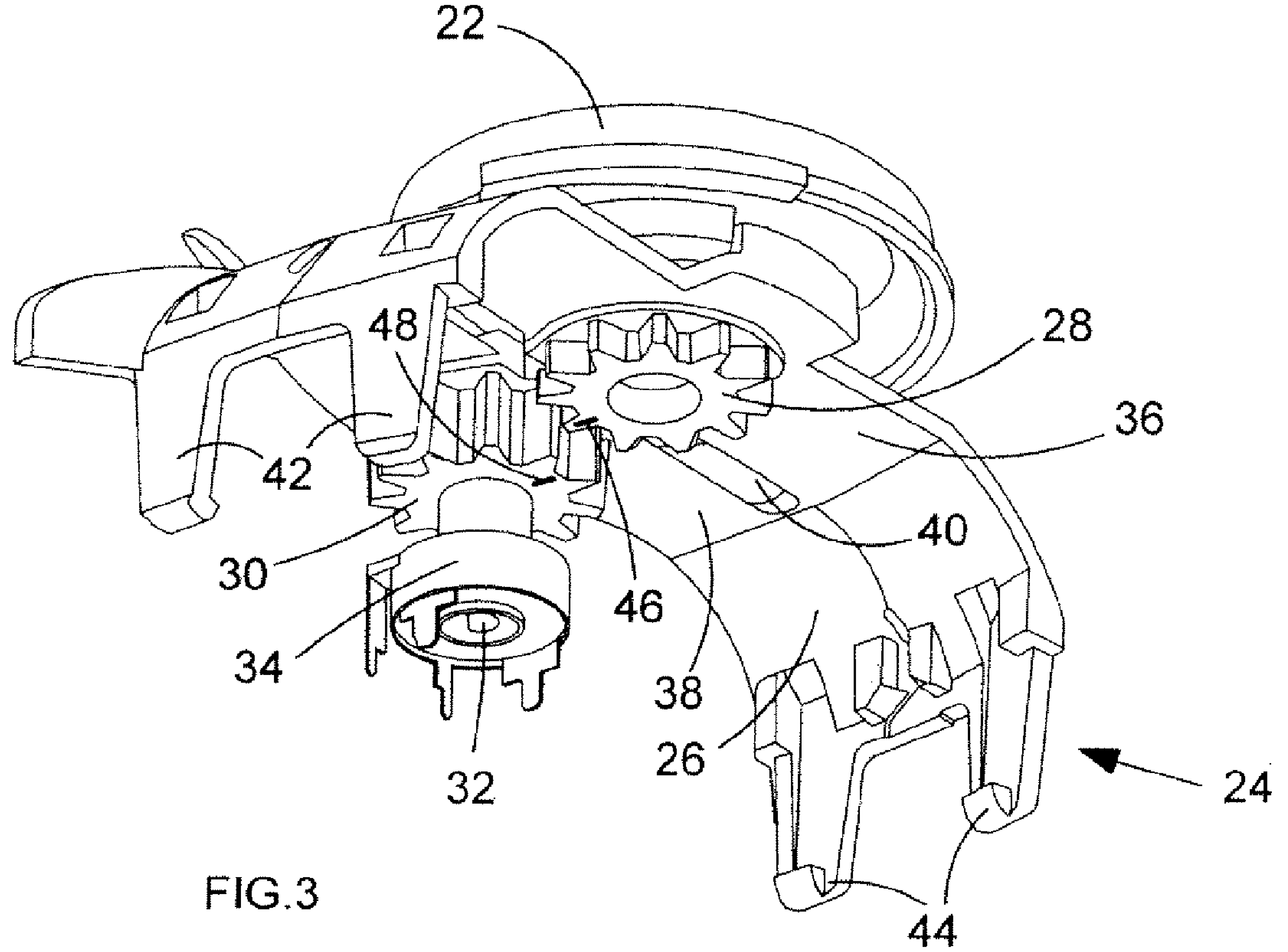

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FIG.3

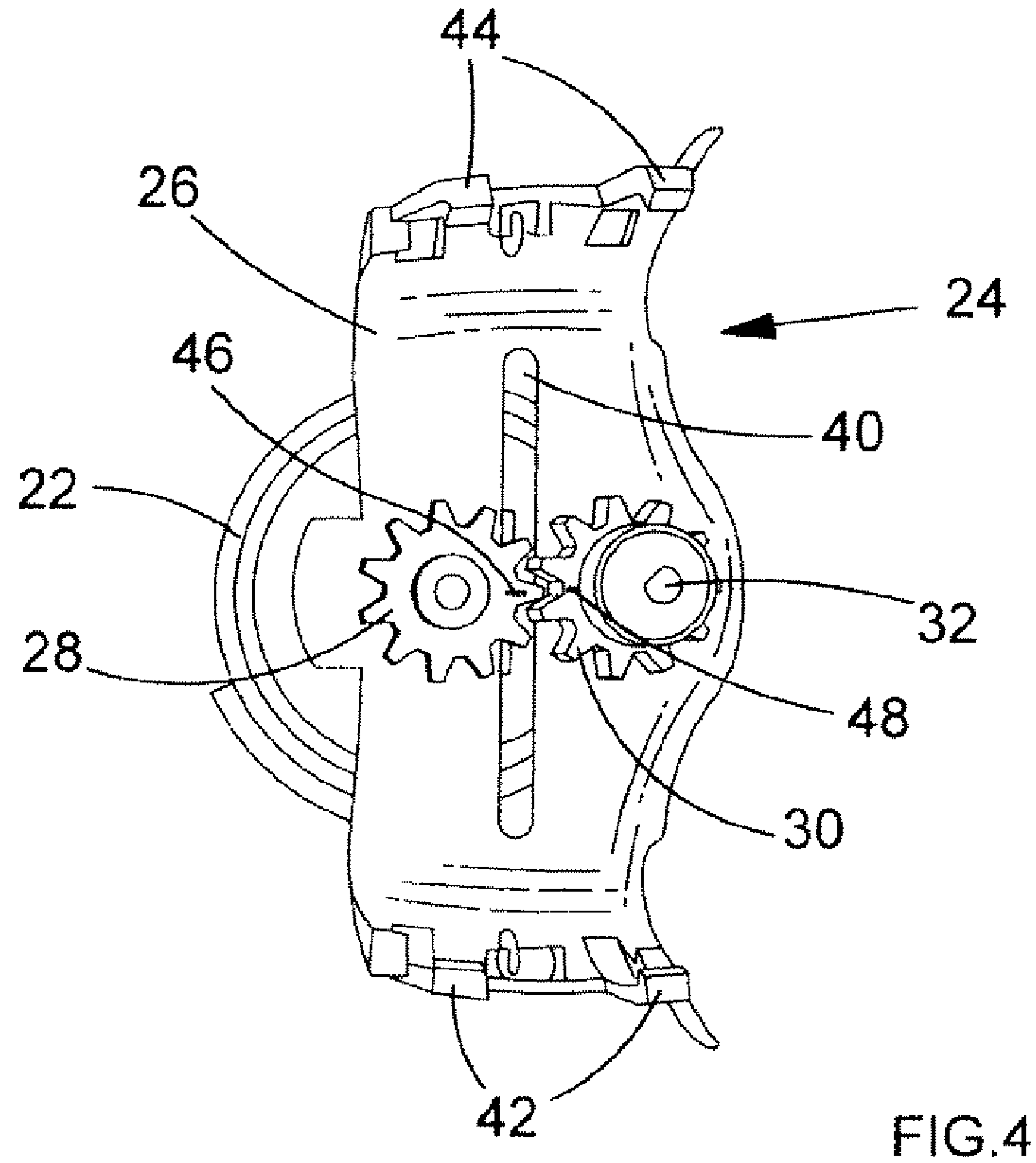
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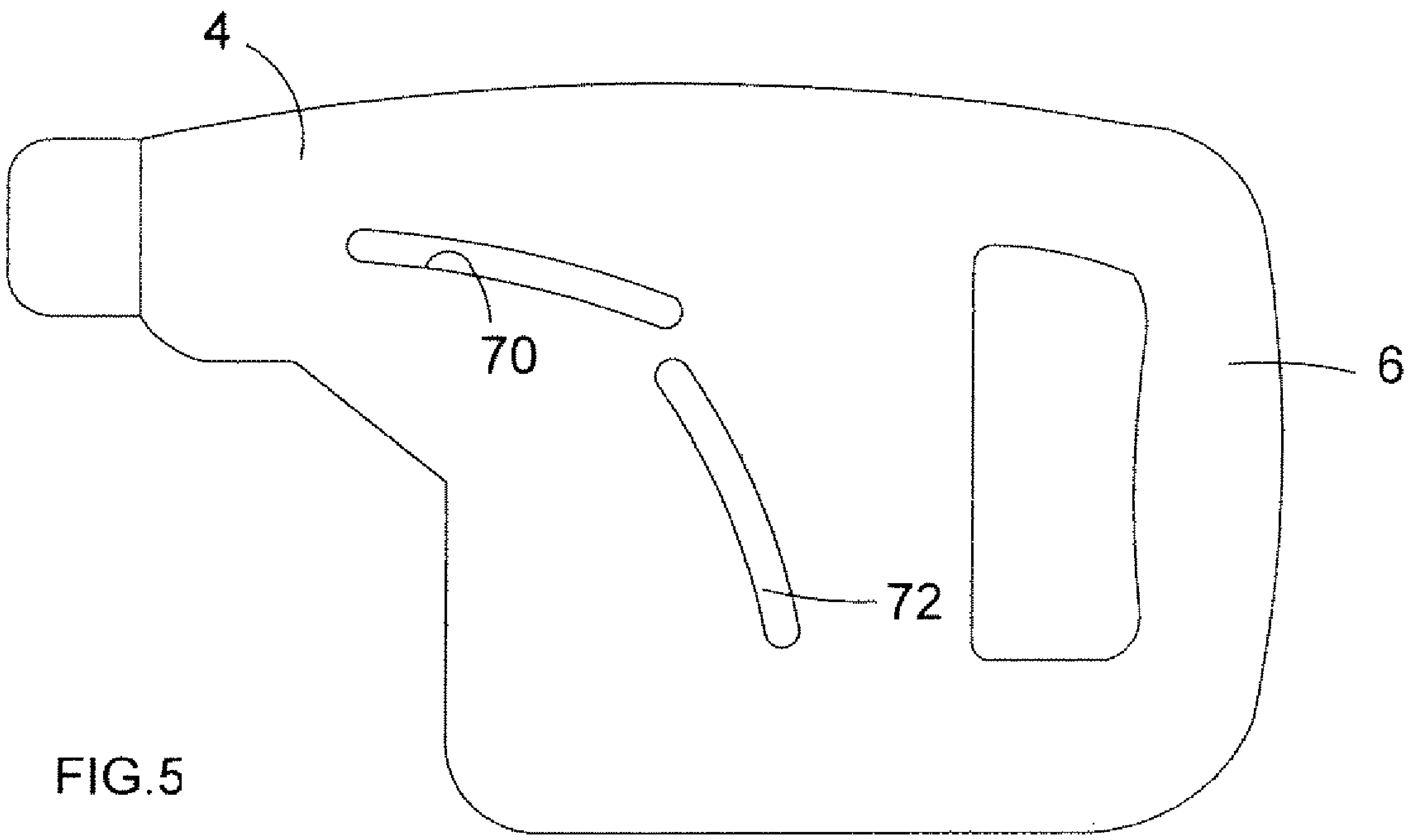
FIG.4



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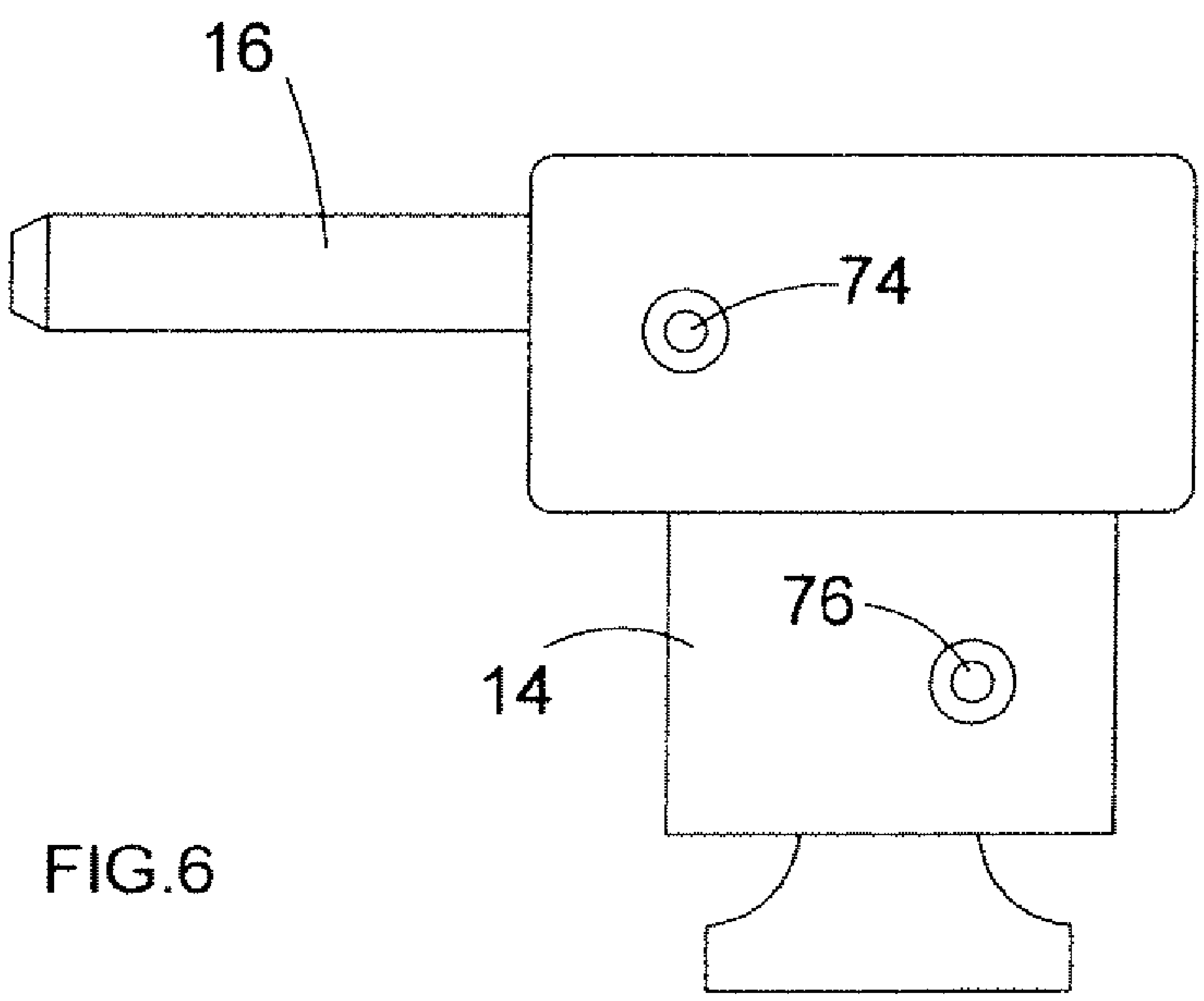

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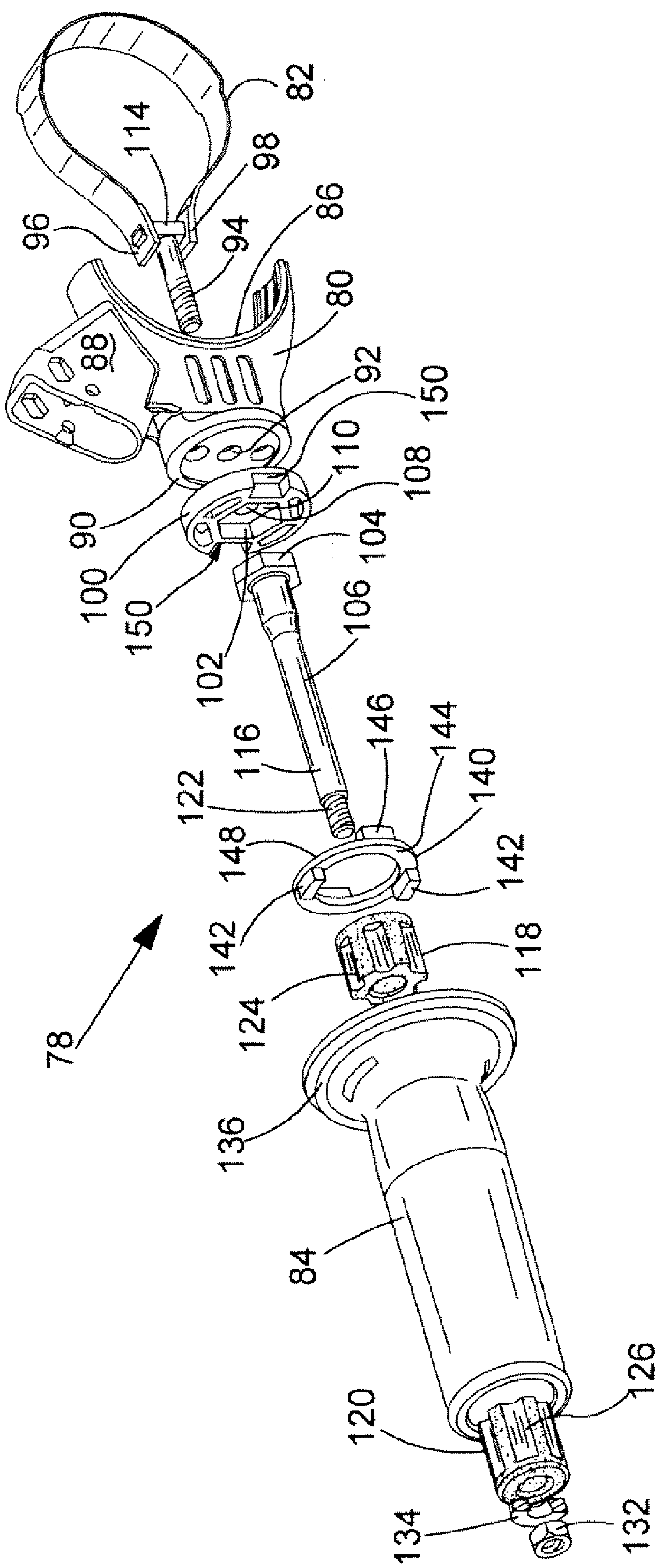
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FIG.7

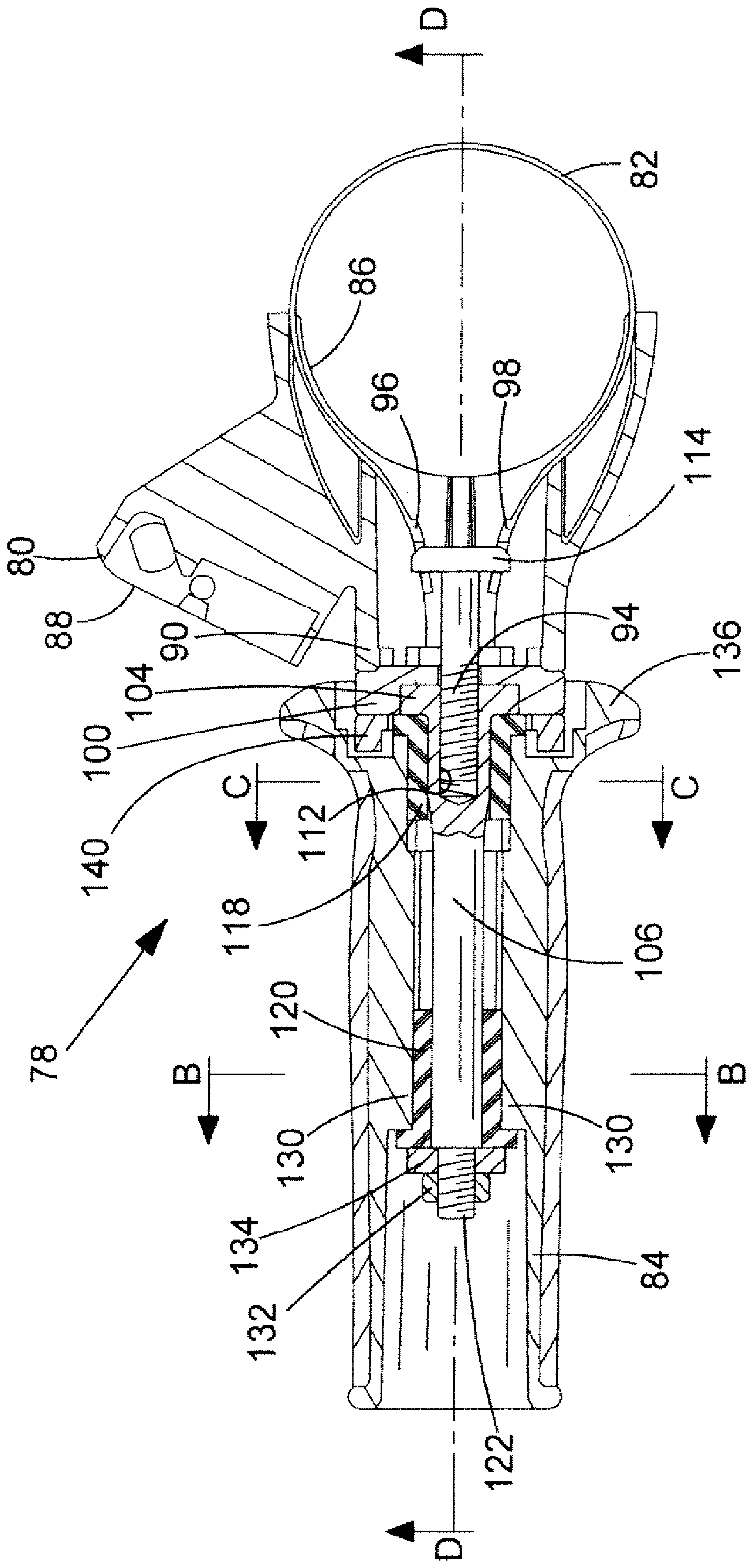
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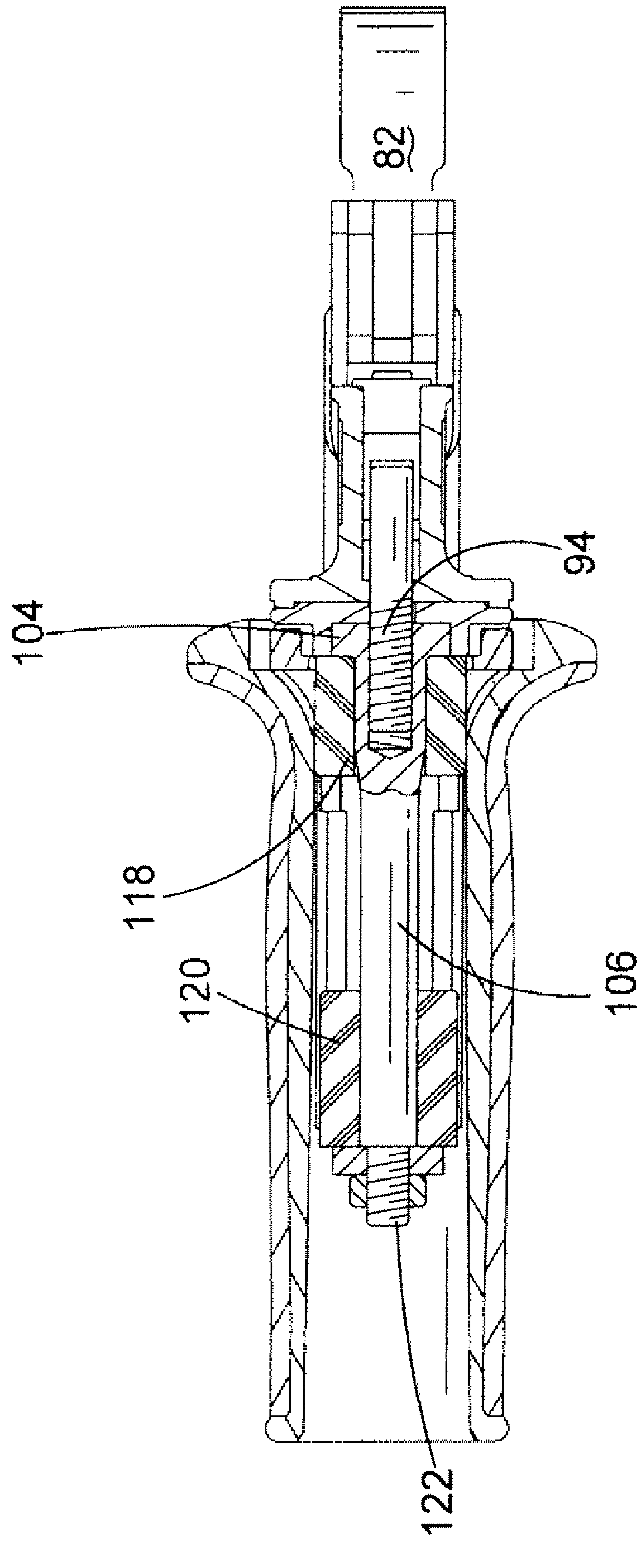
FIG.8



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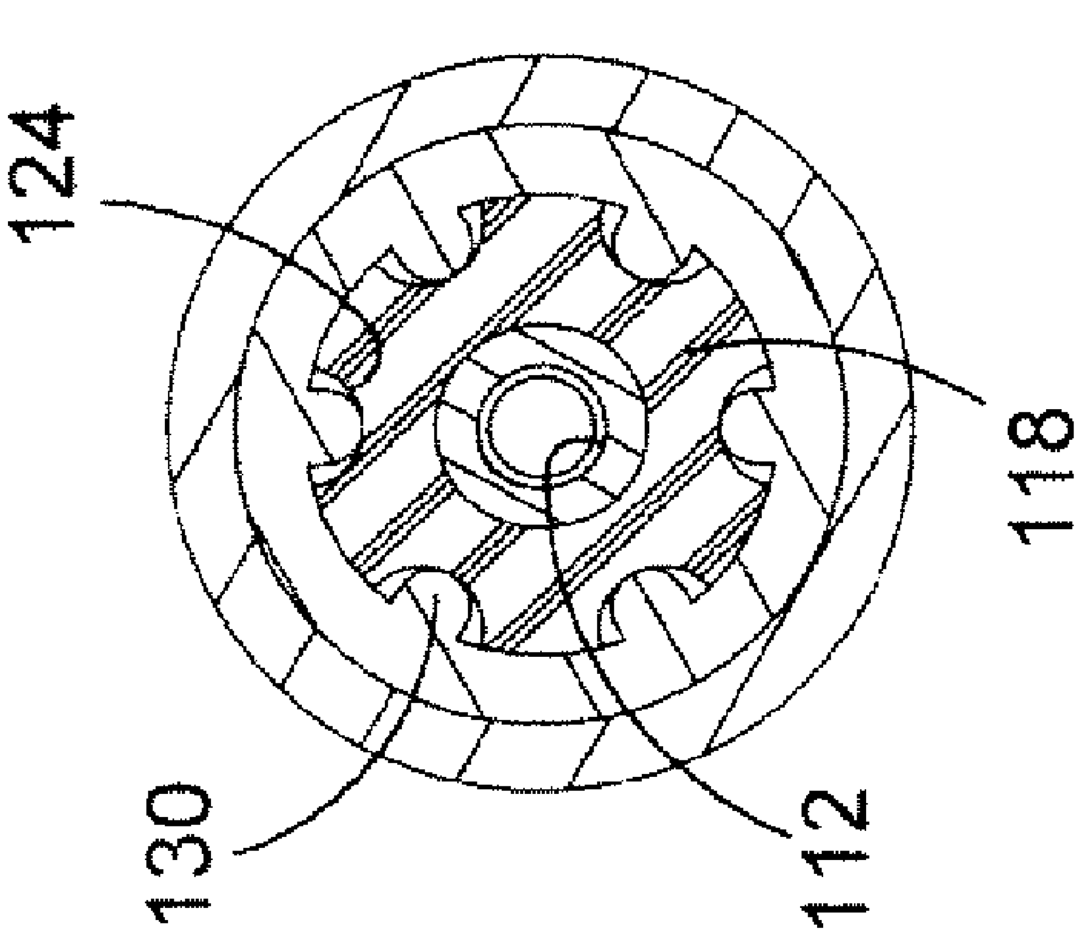
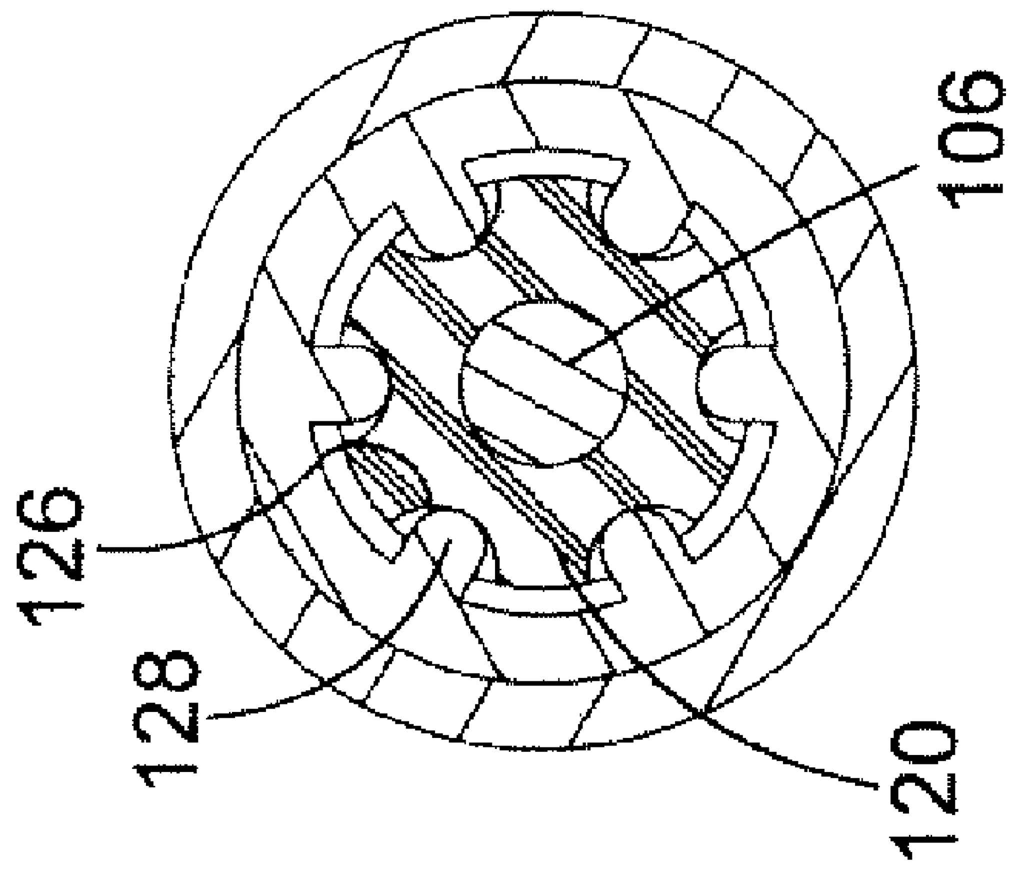


FIG.12



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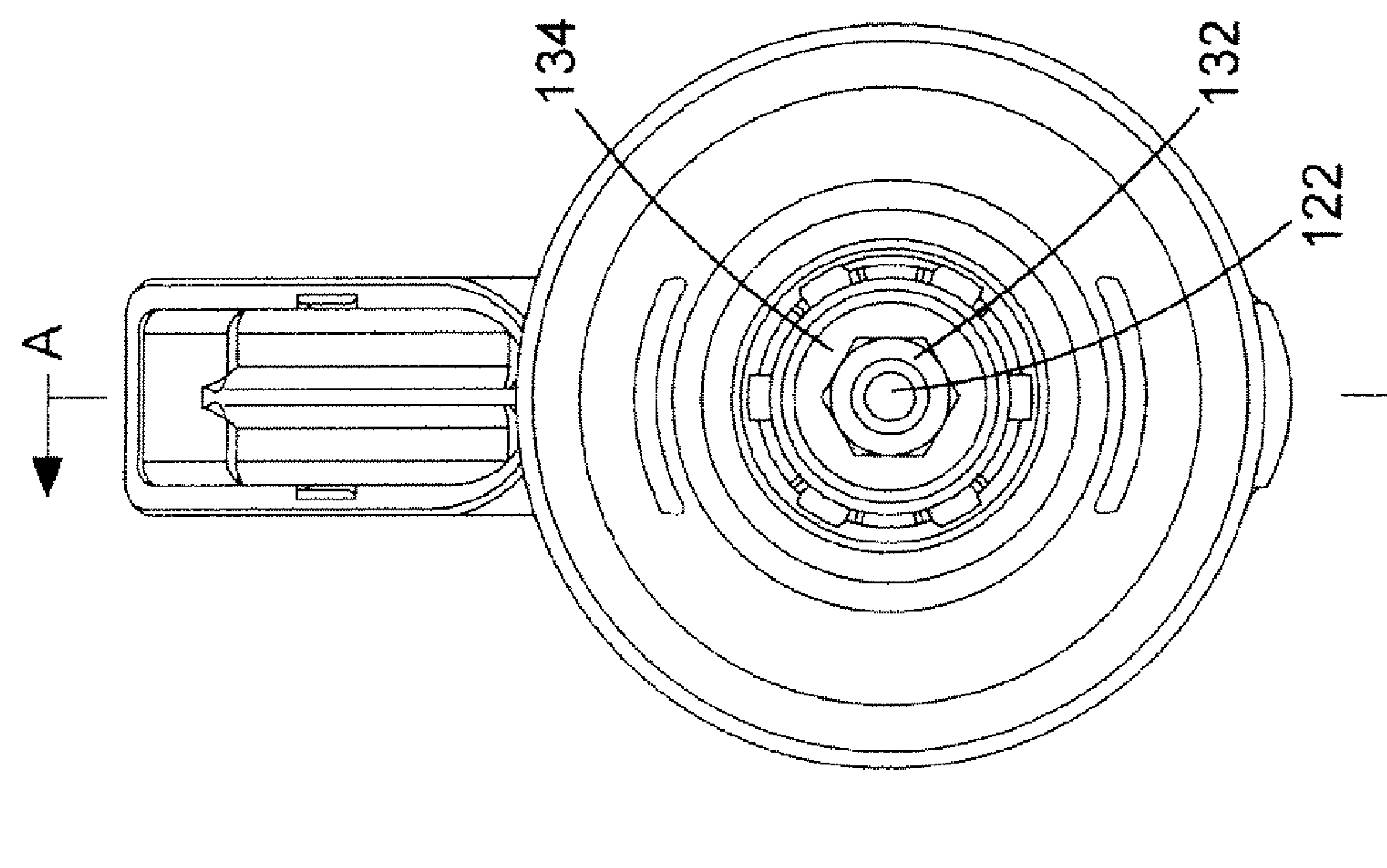
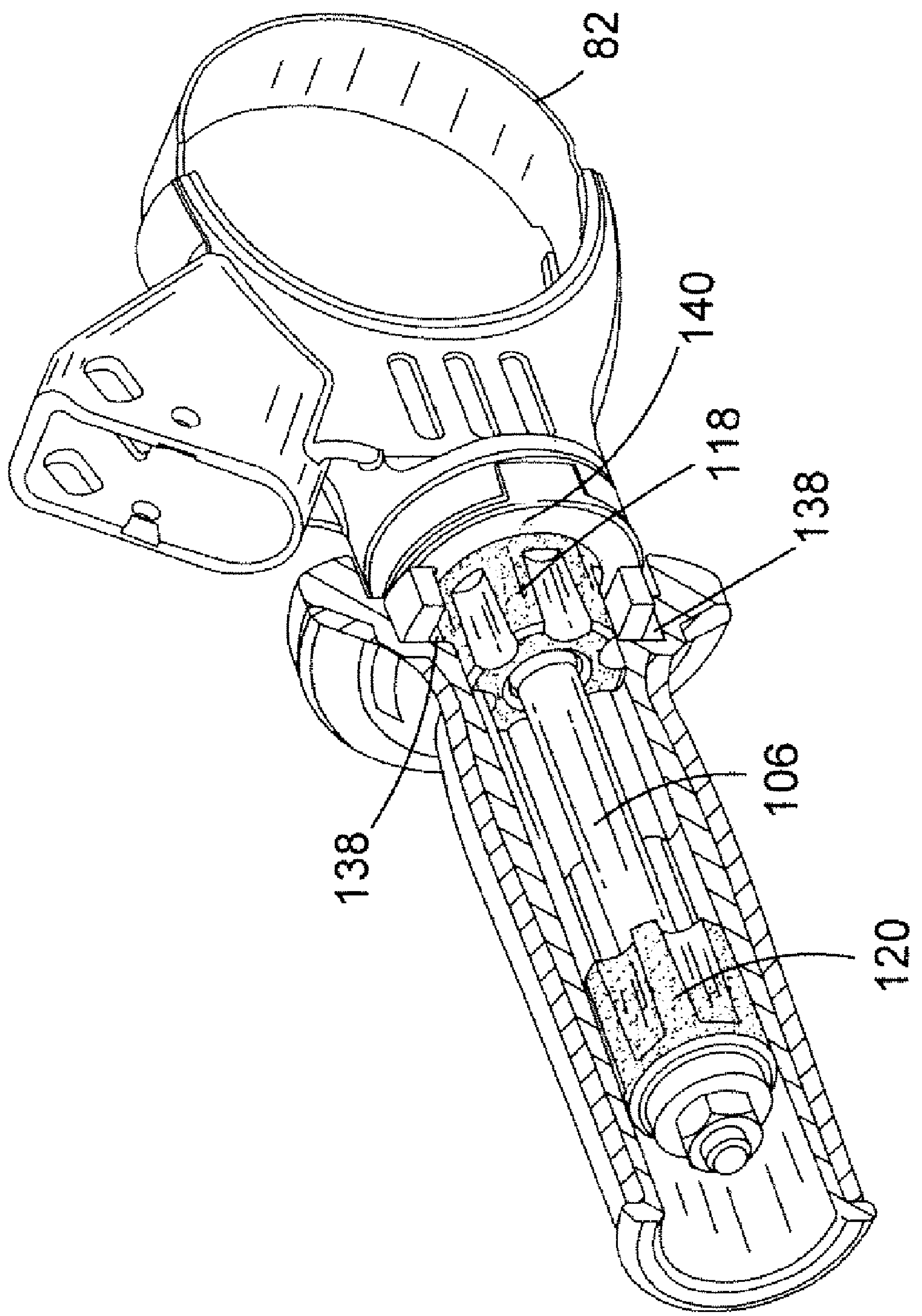


FIG.10



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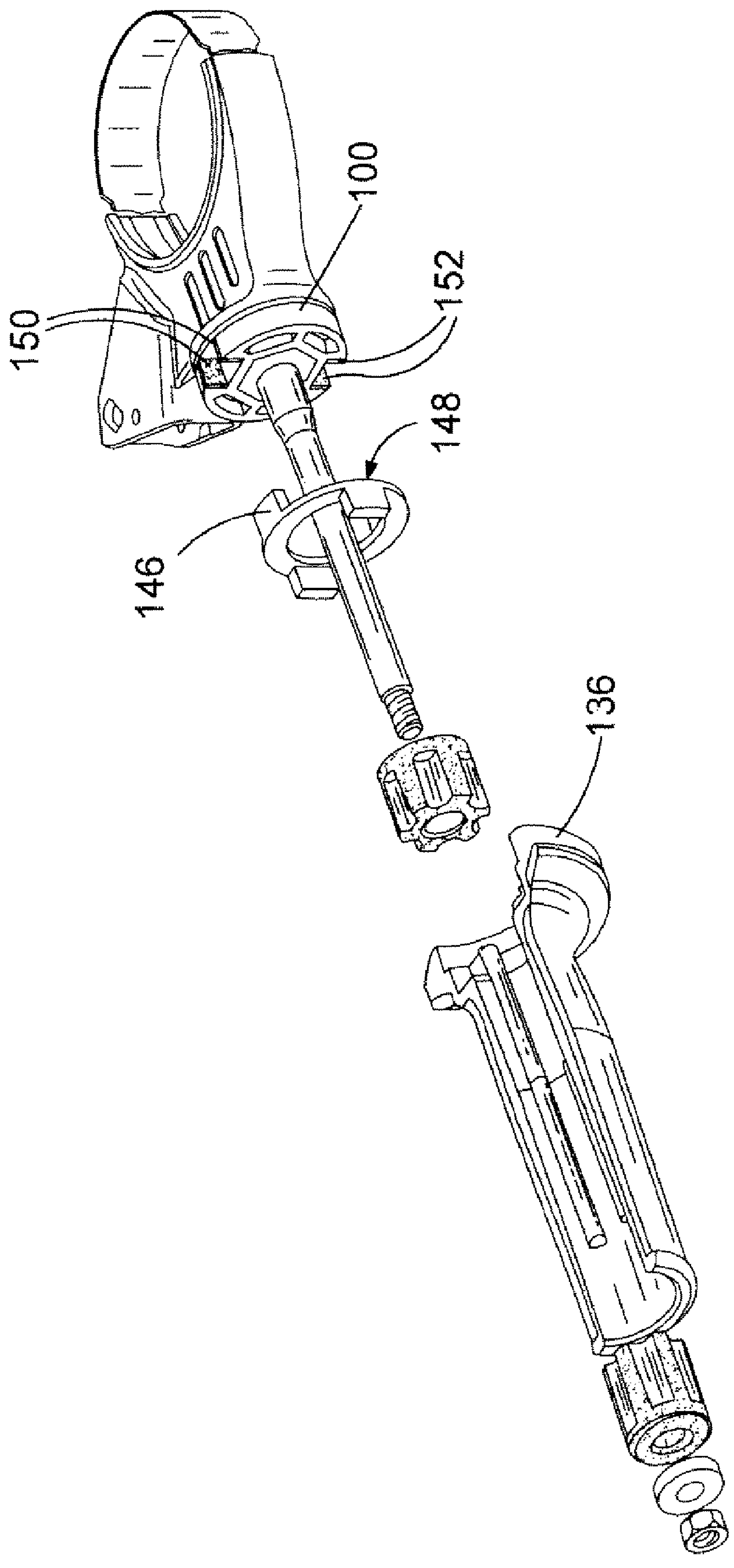

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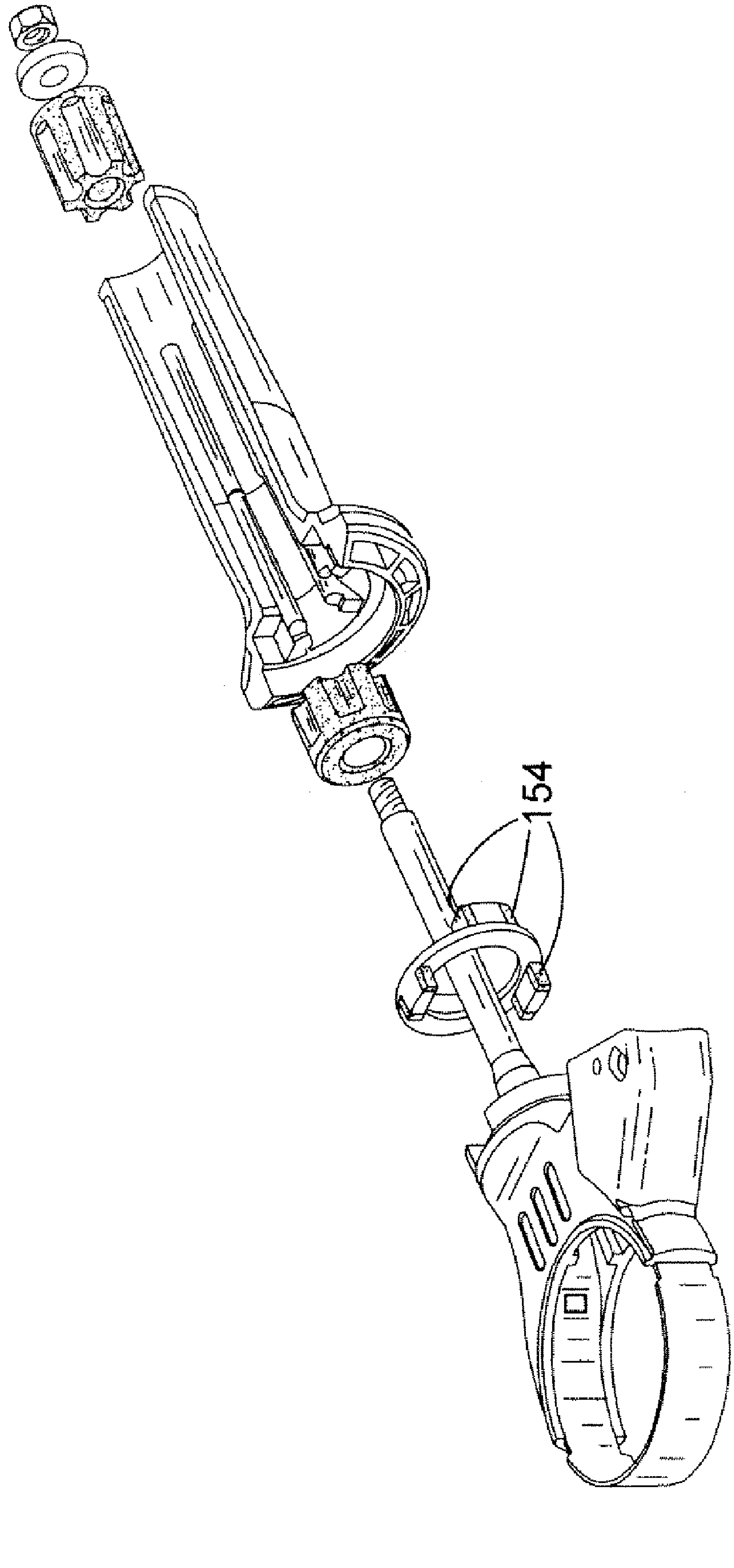

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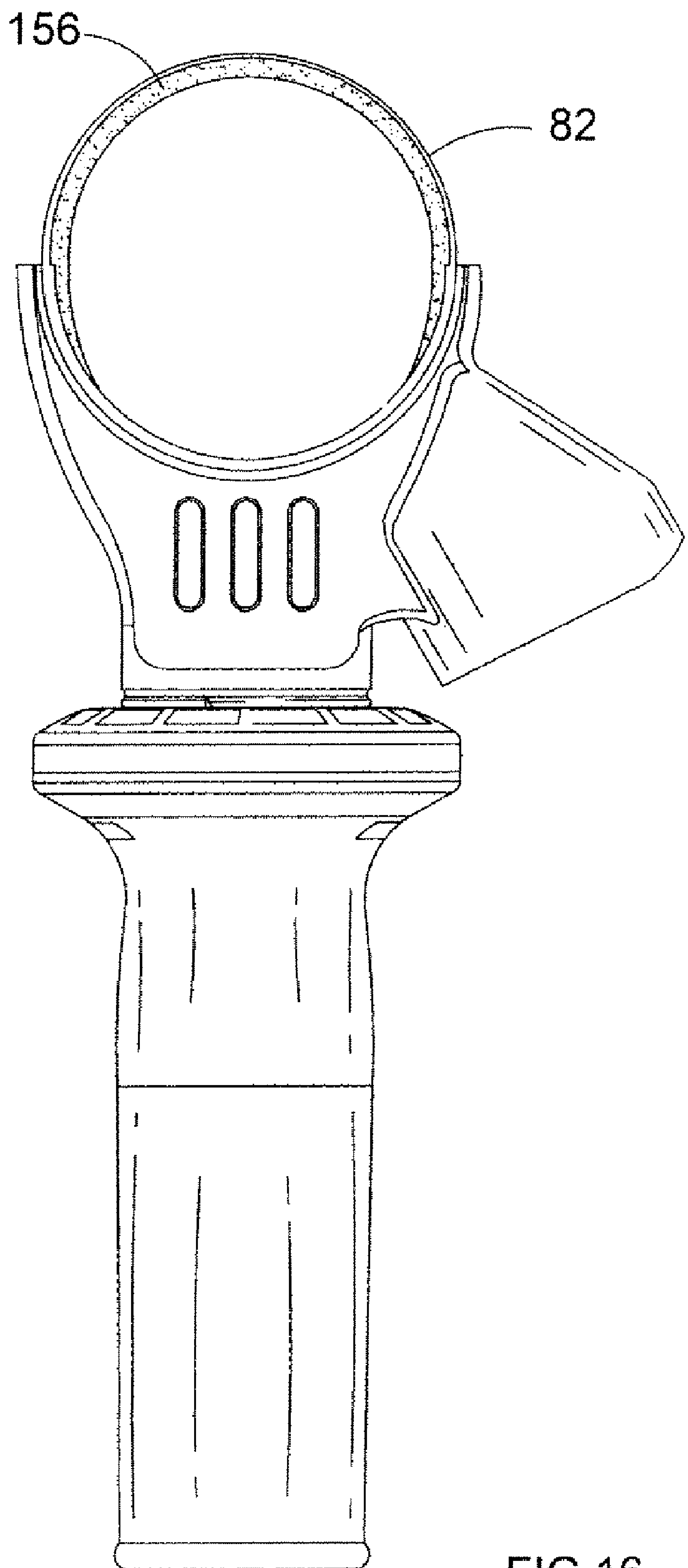

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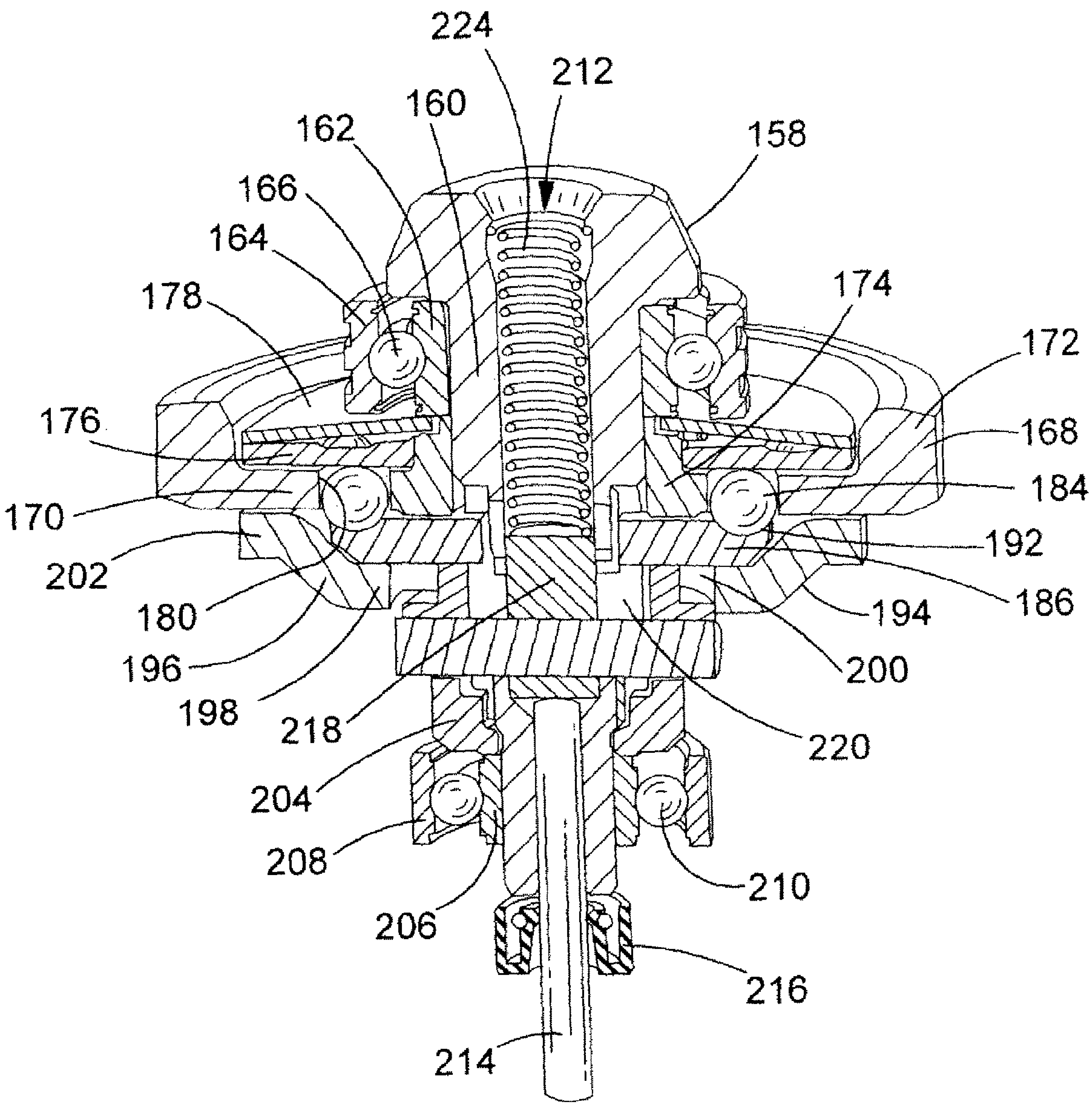
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FIG.17

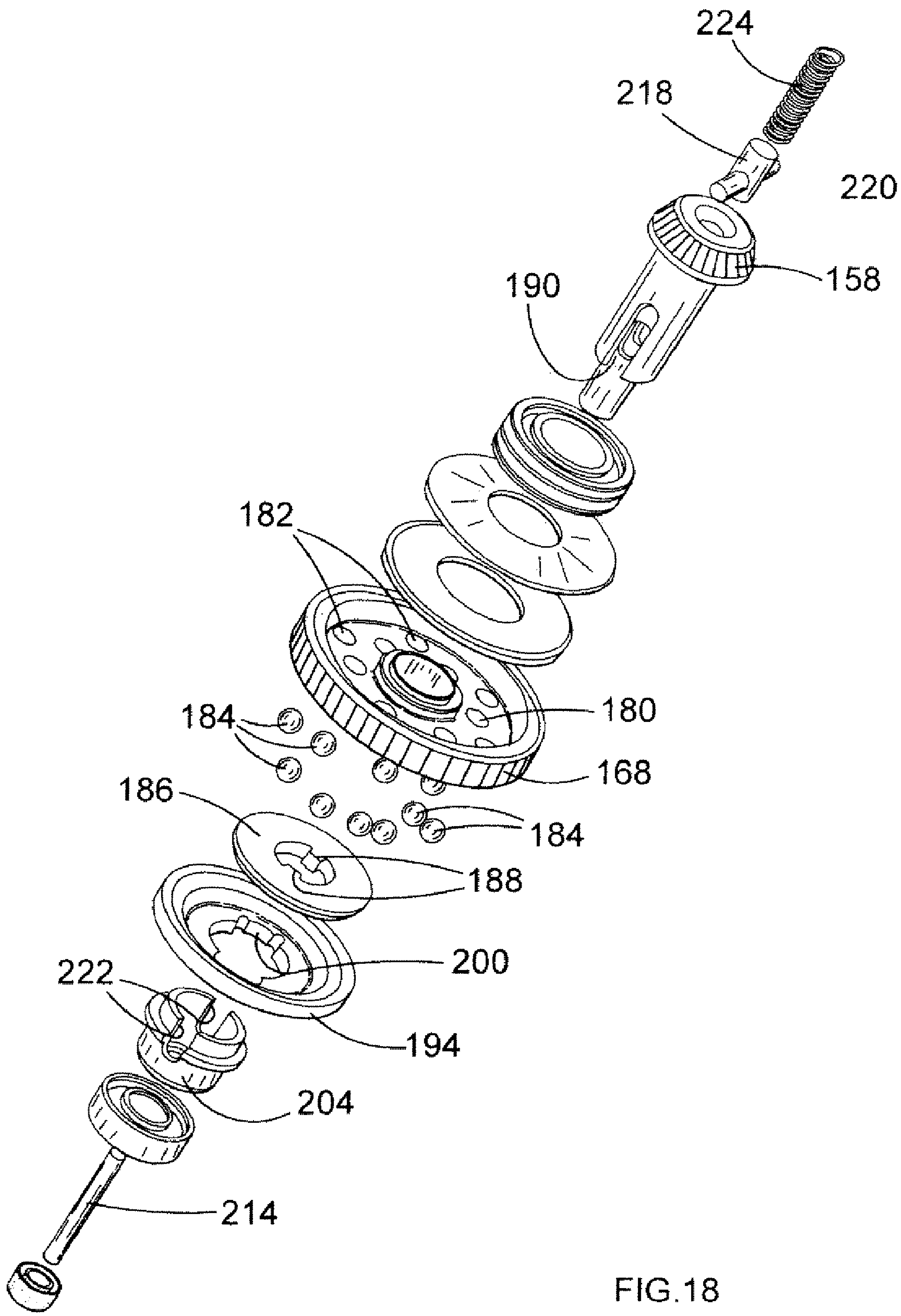
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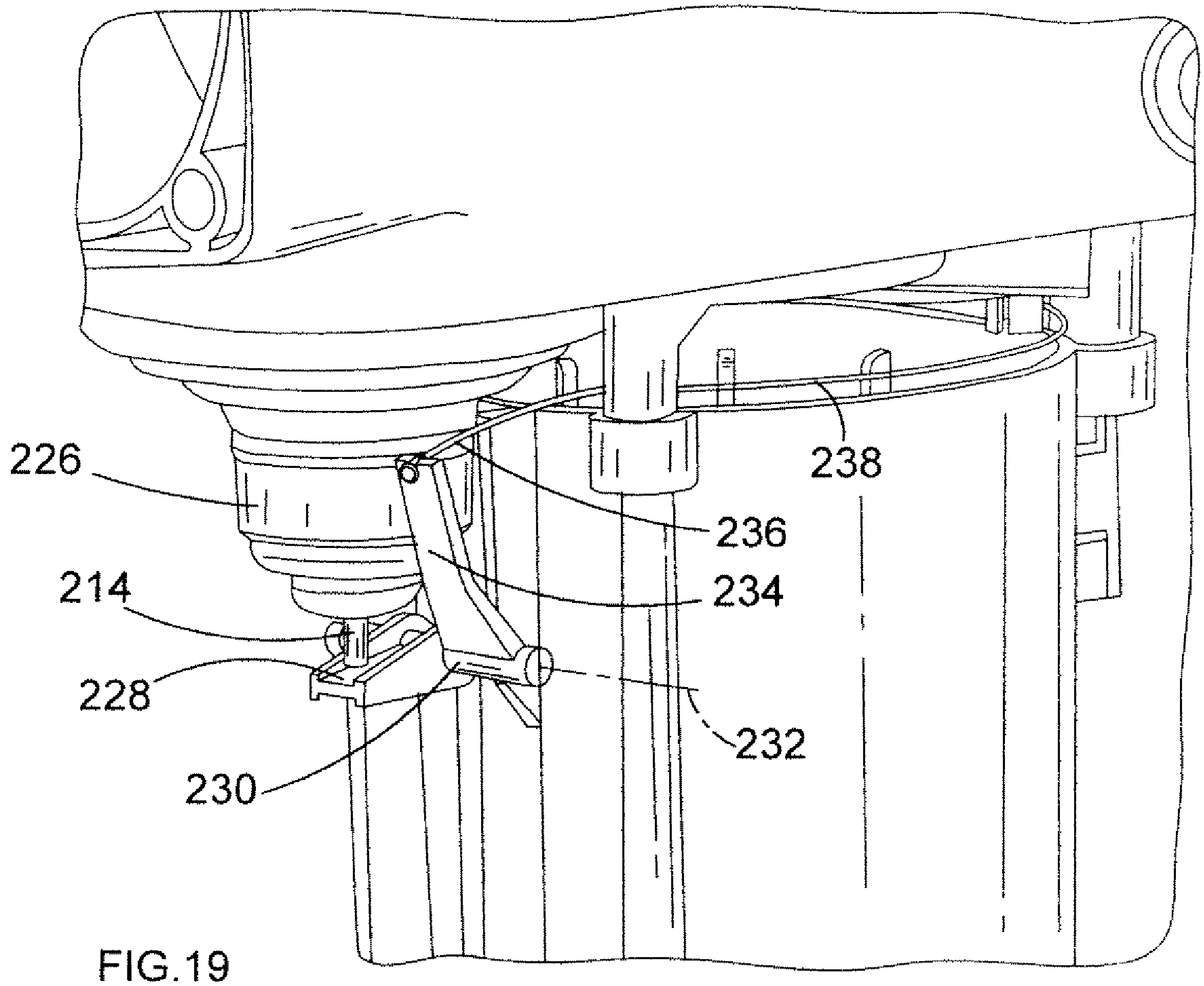
FIG.18



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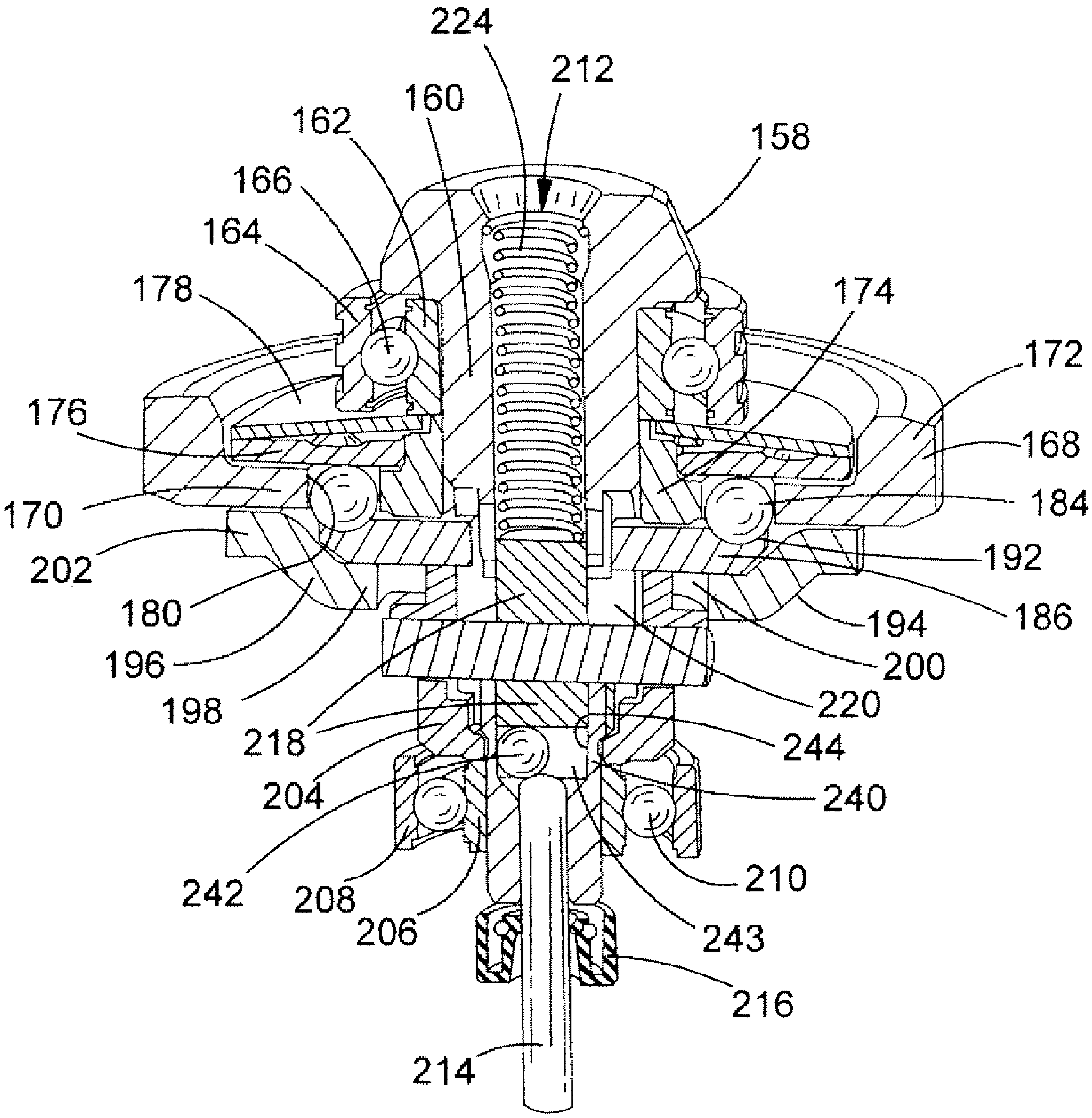
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FIG.20

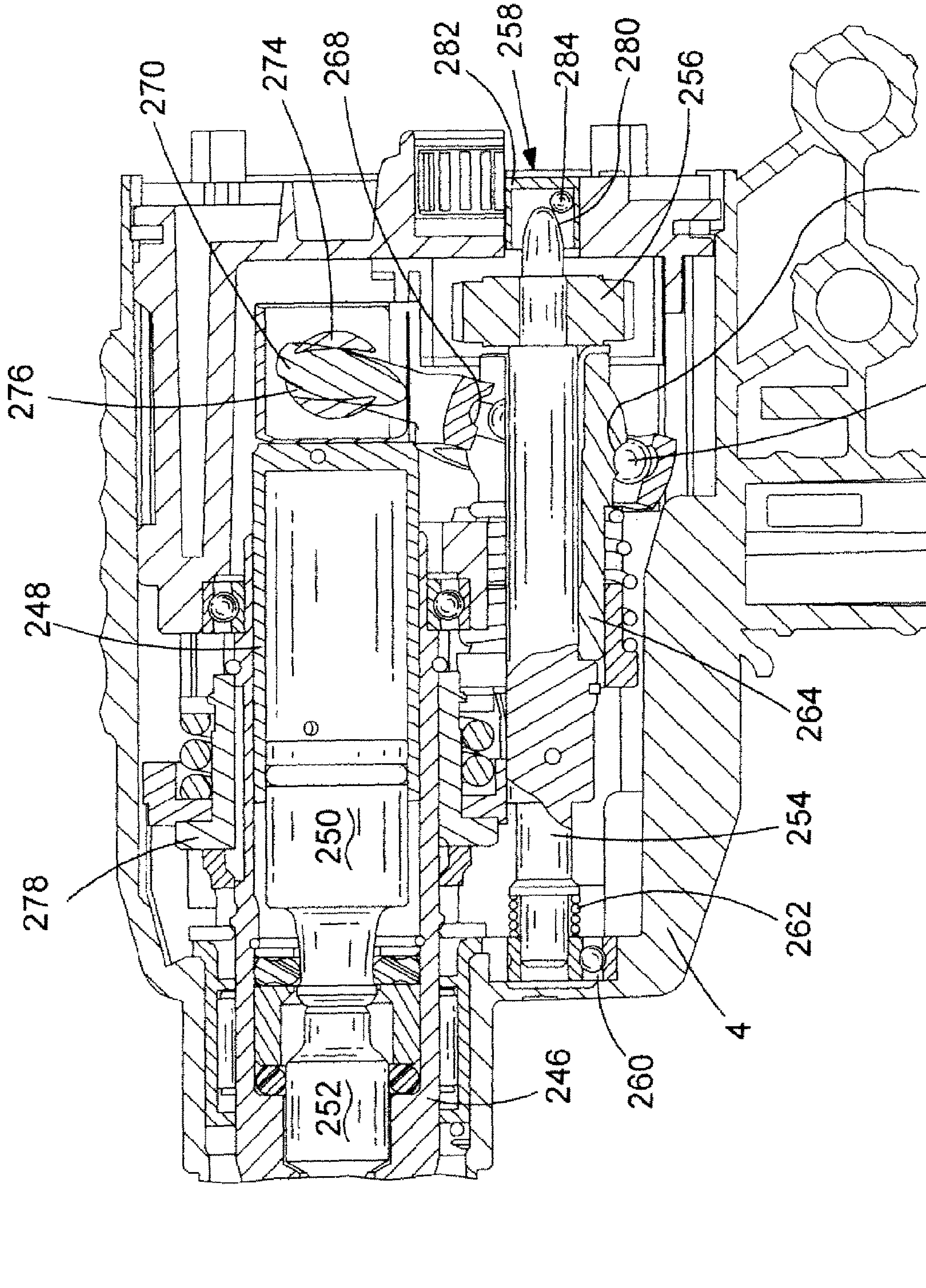
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FIG.21

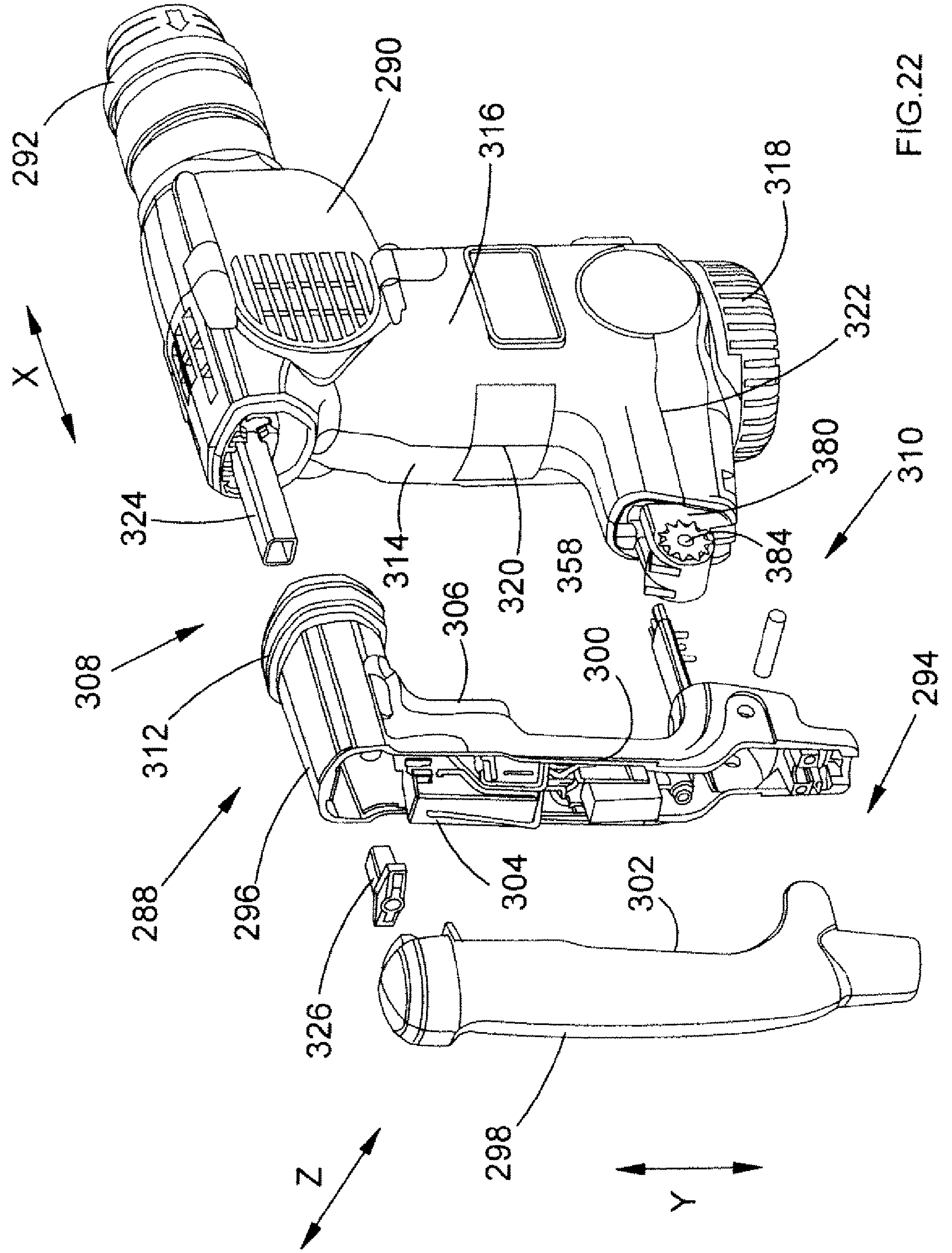
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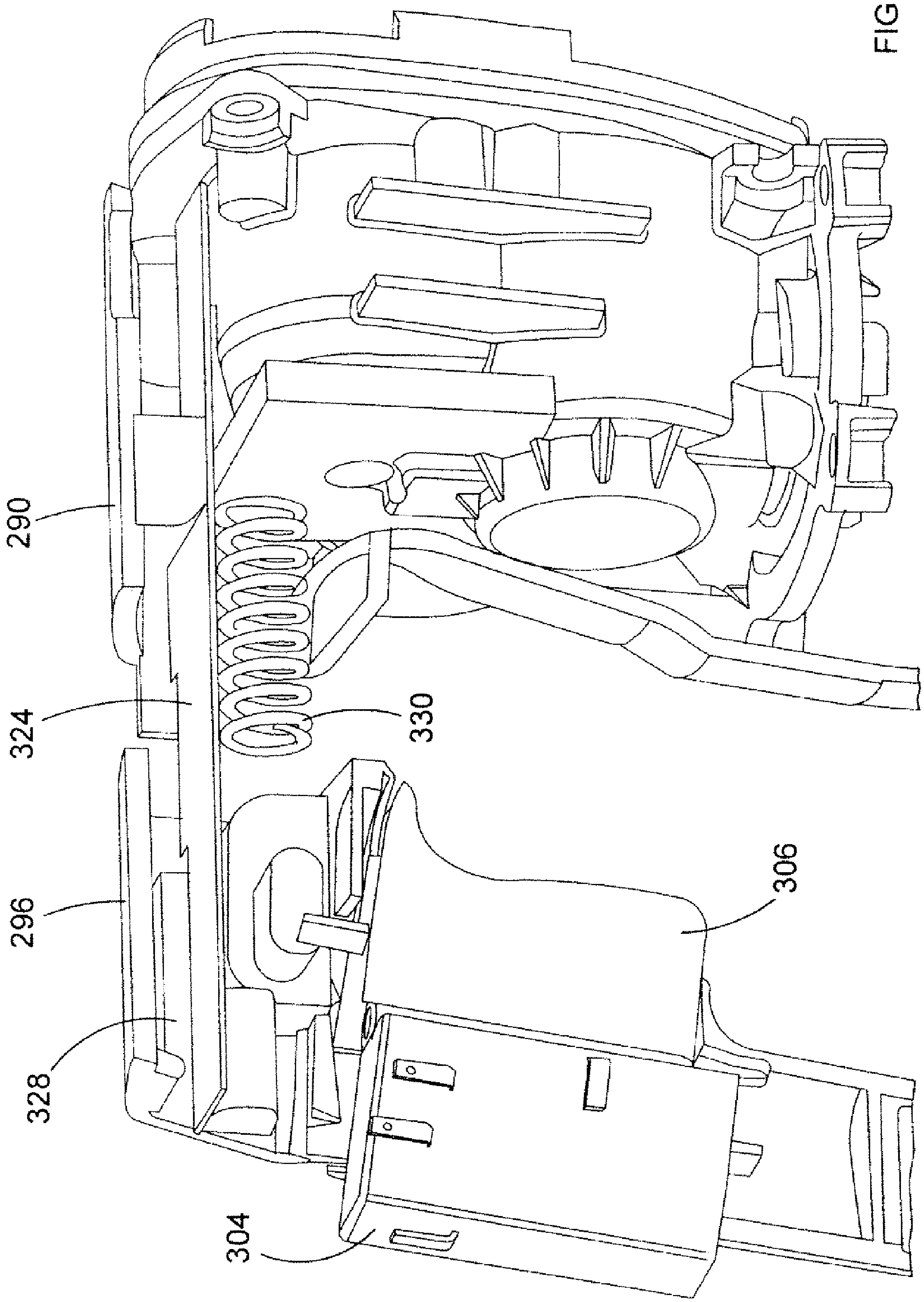
FIG.22



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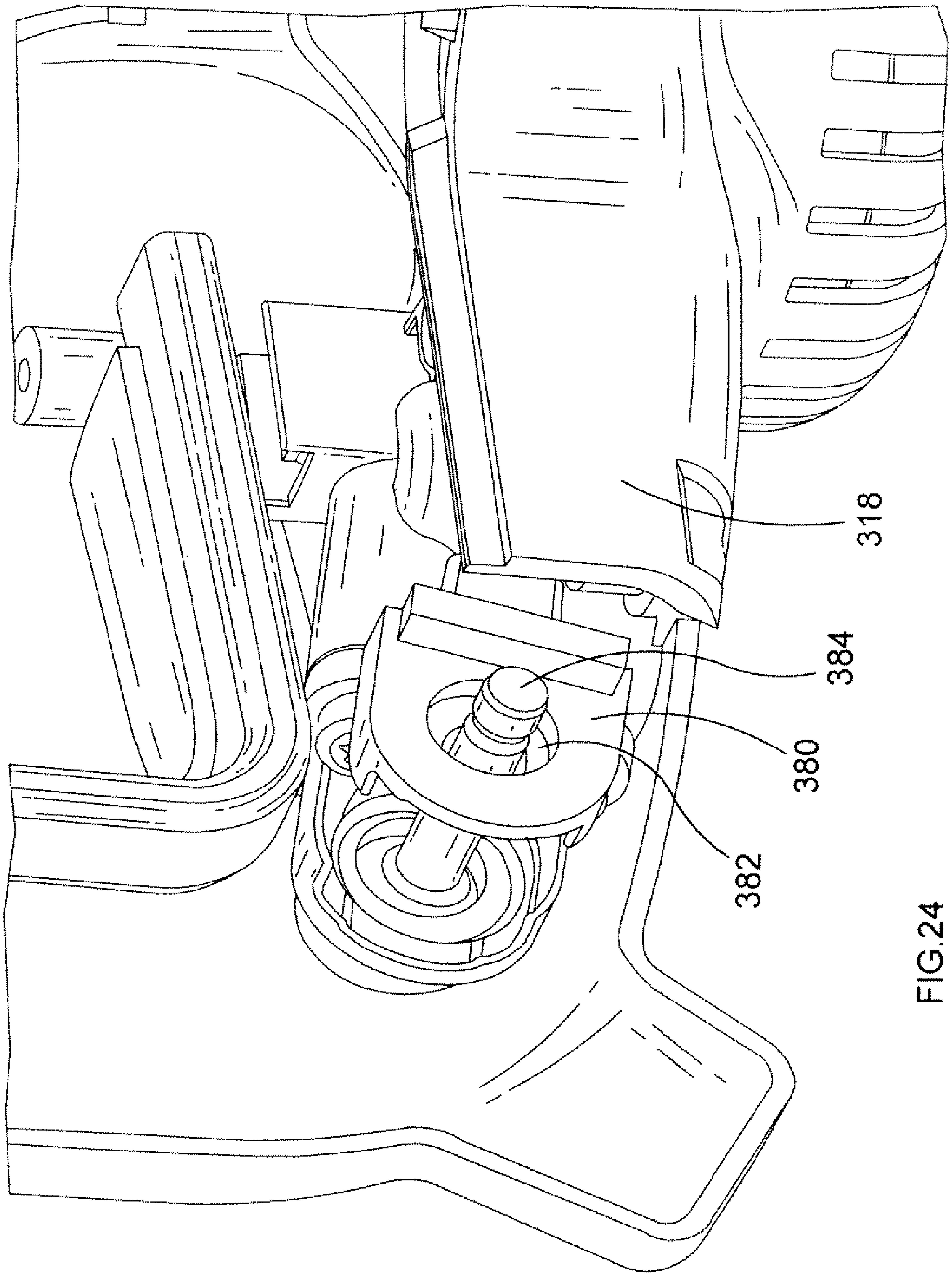

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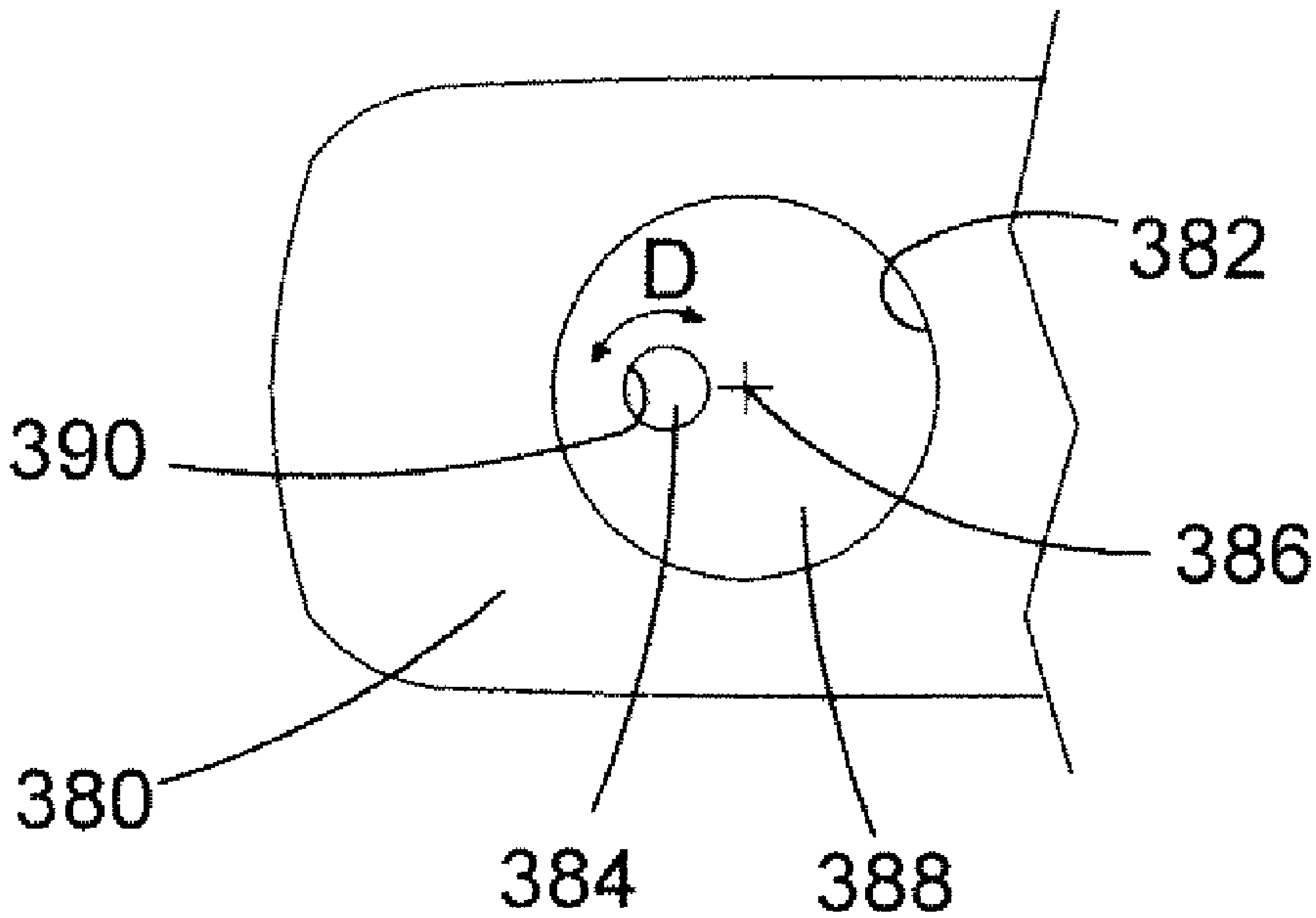

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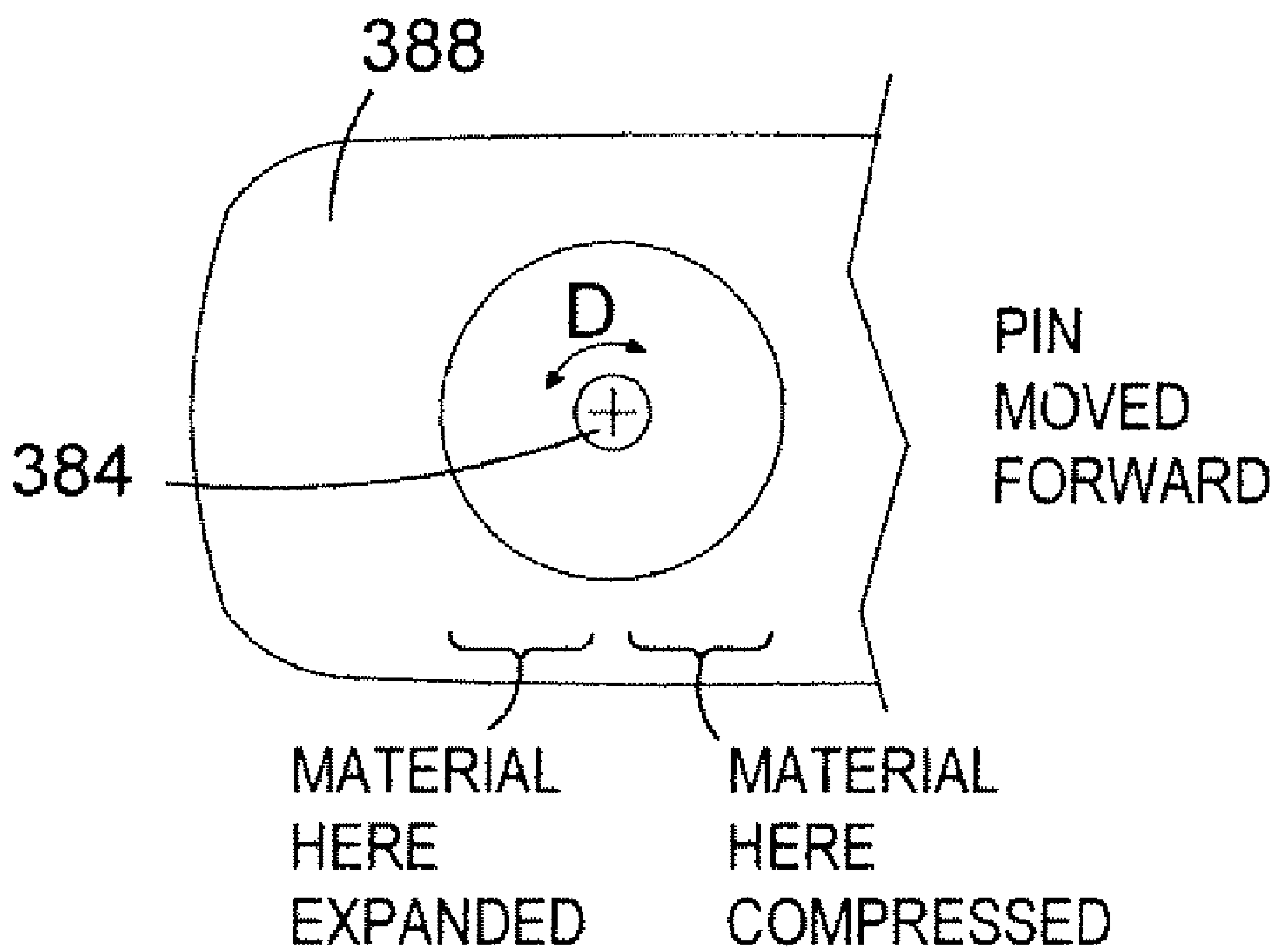
FIG.25



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MATERIAL
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EXPANDED
MATERIAL
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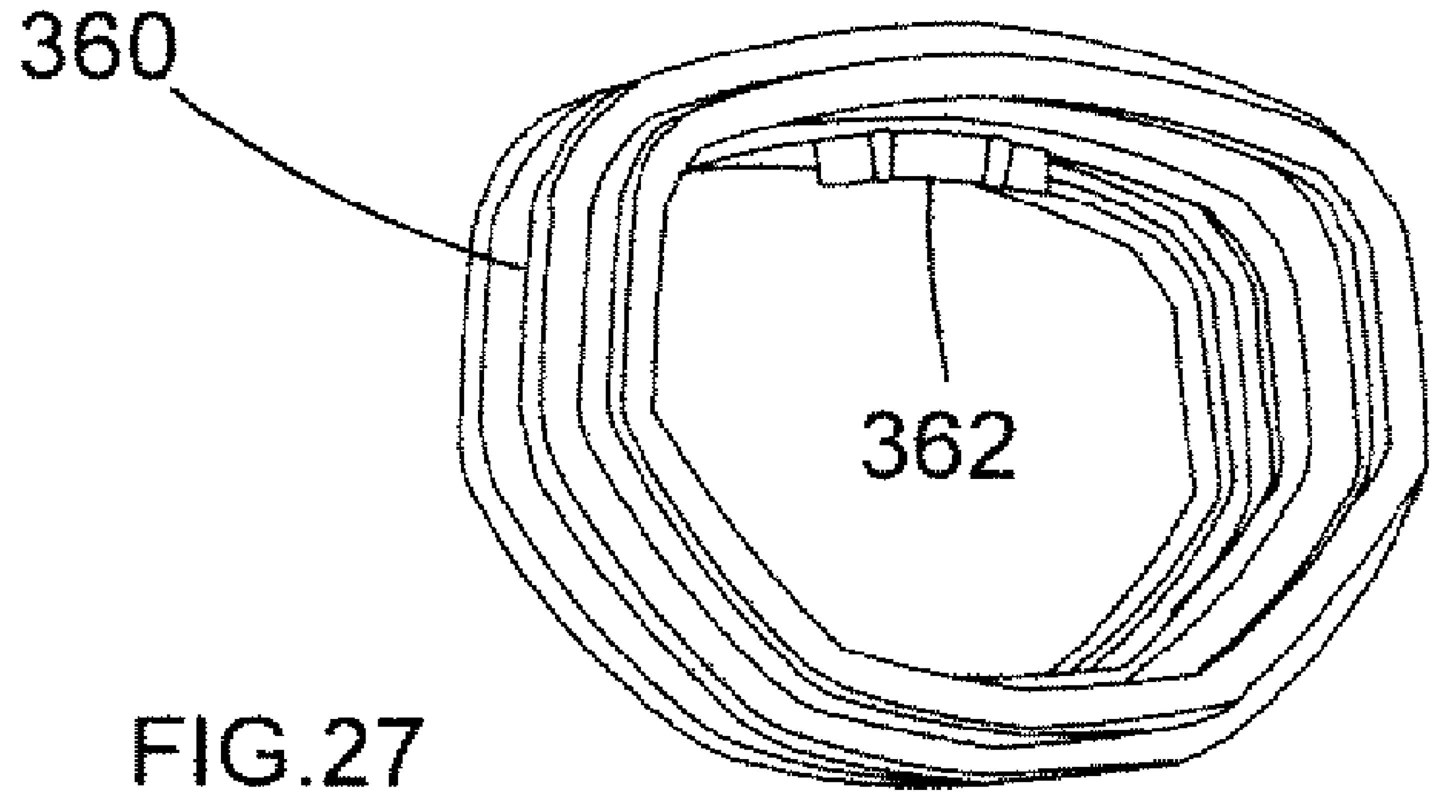
FIG.26



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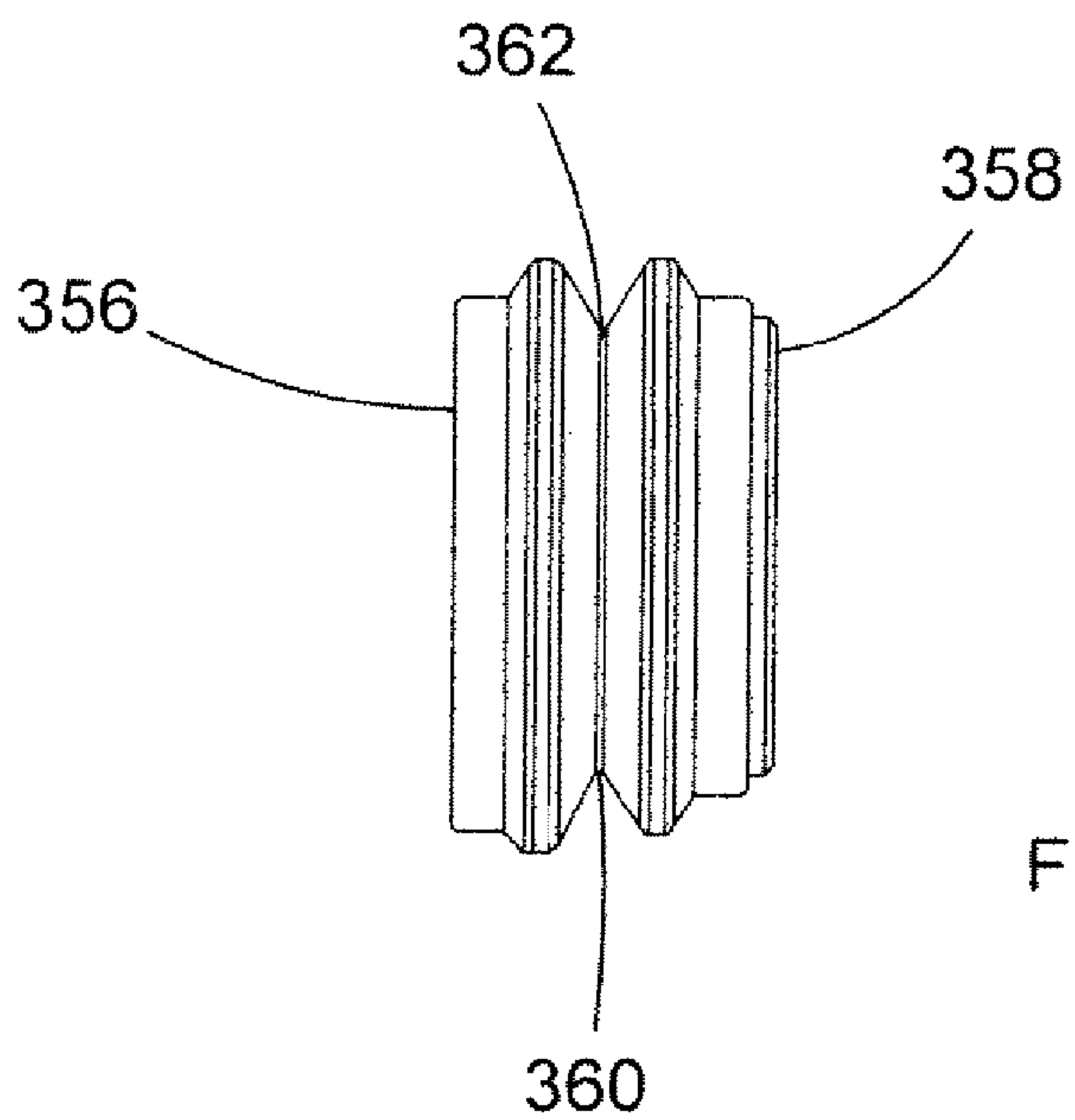


FIG.28

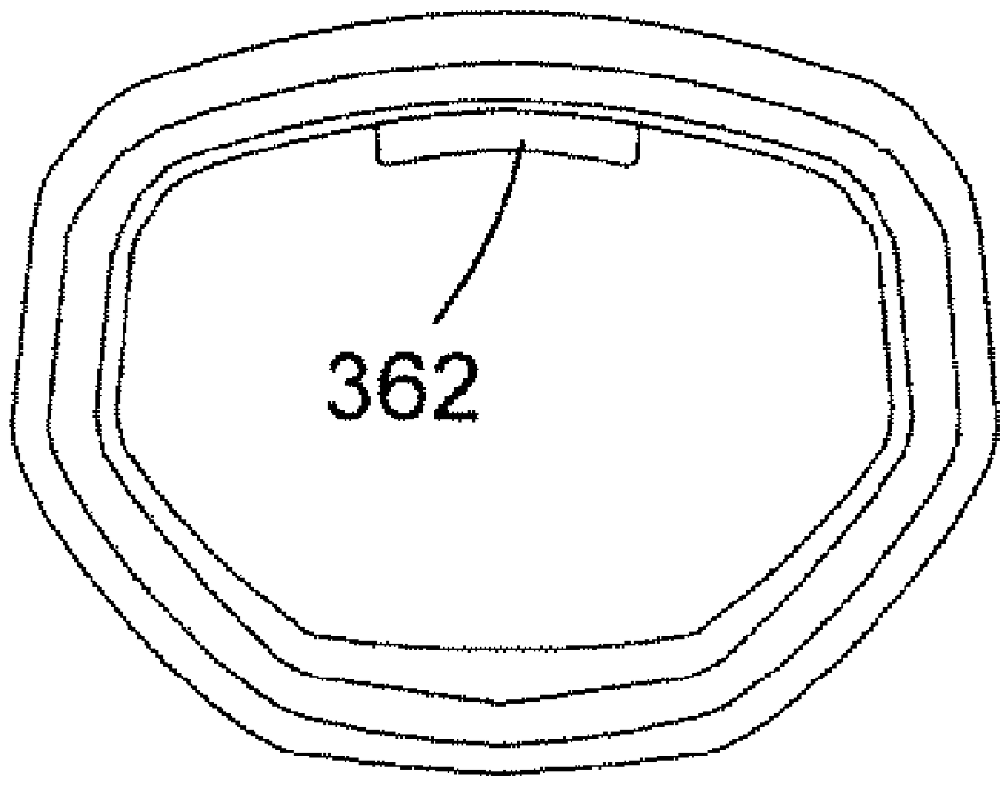


FIG.29

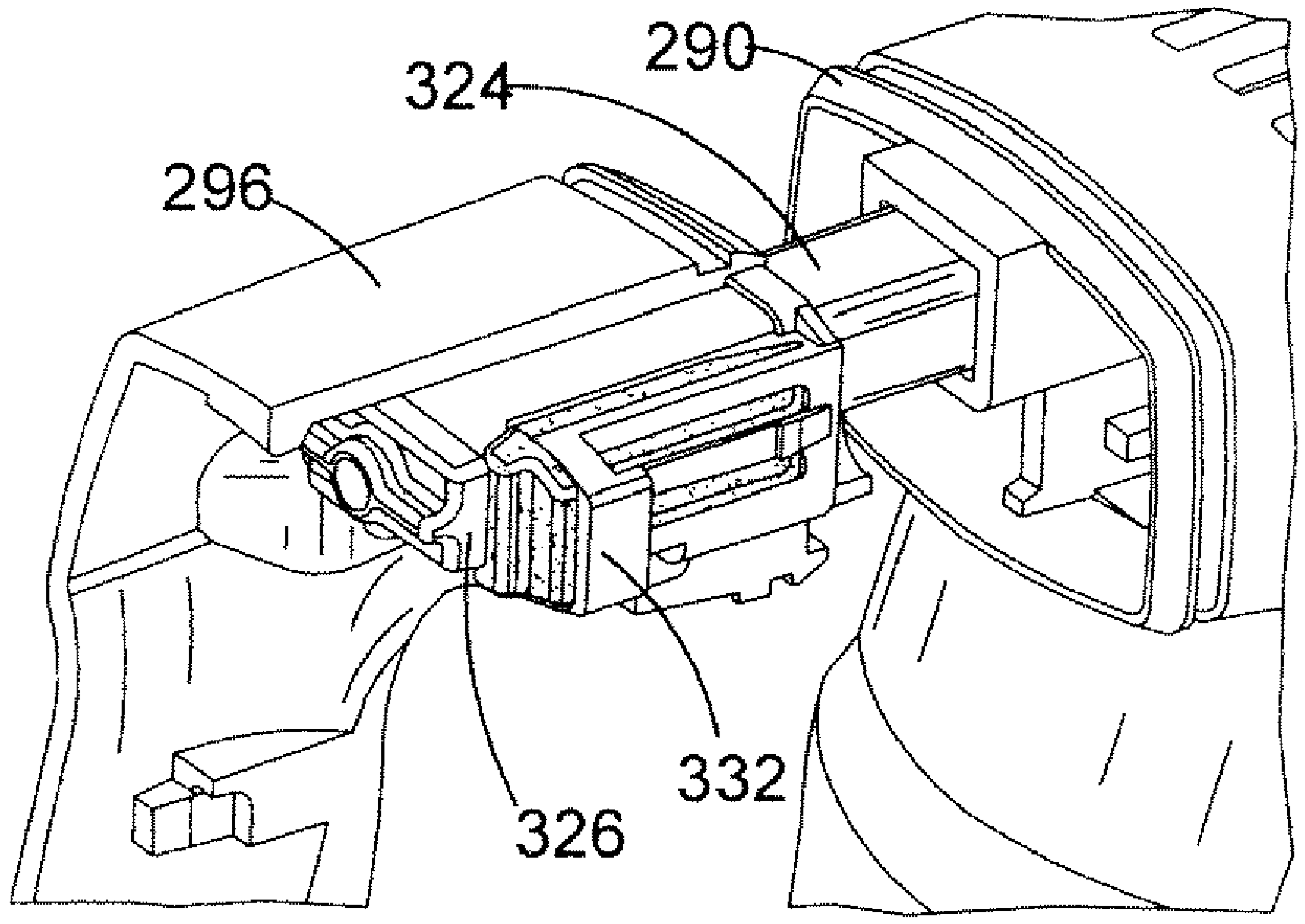


FIG.30

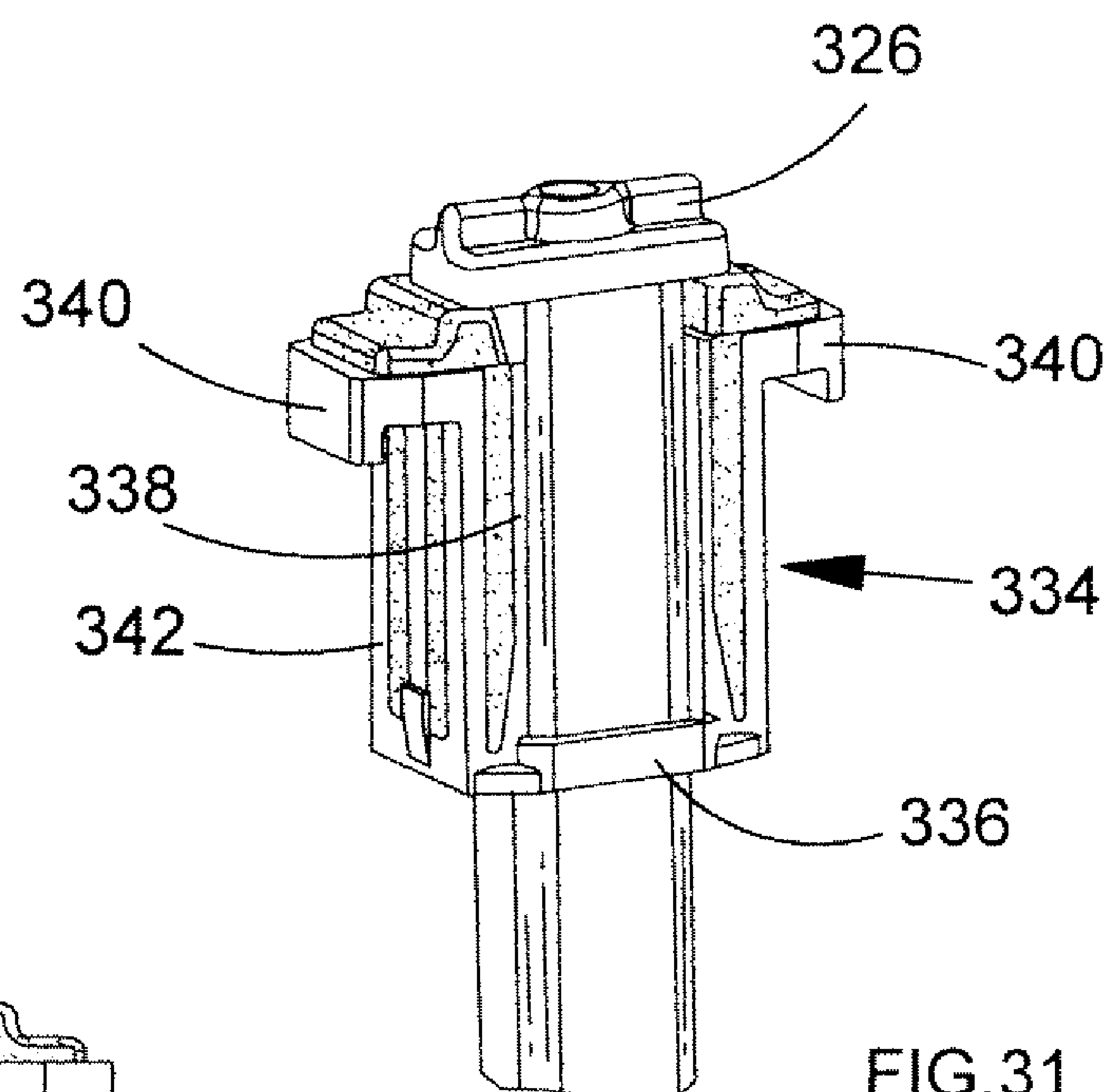
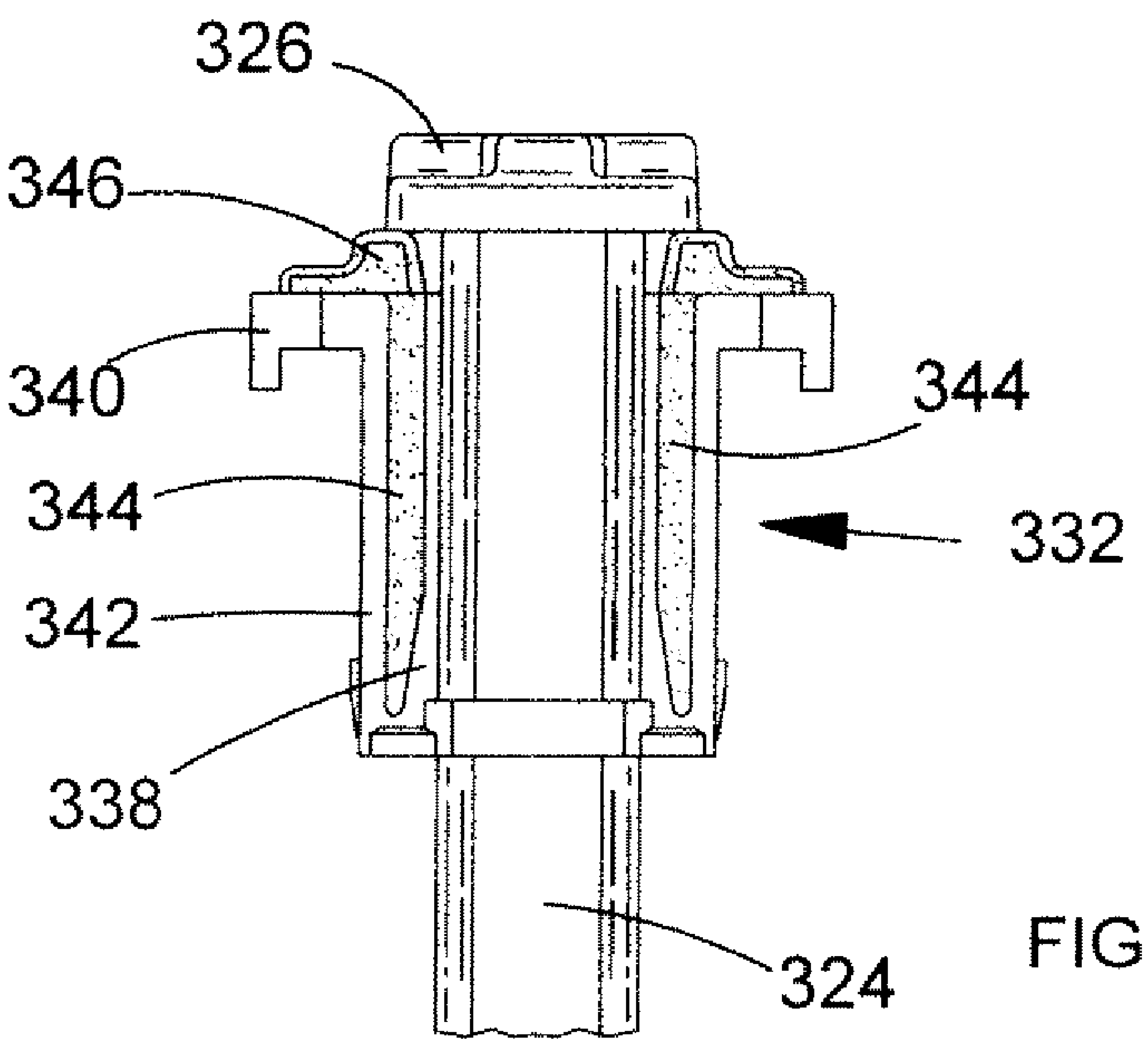


FIG.31



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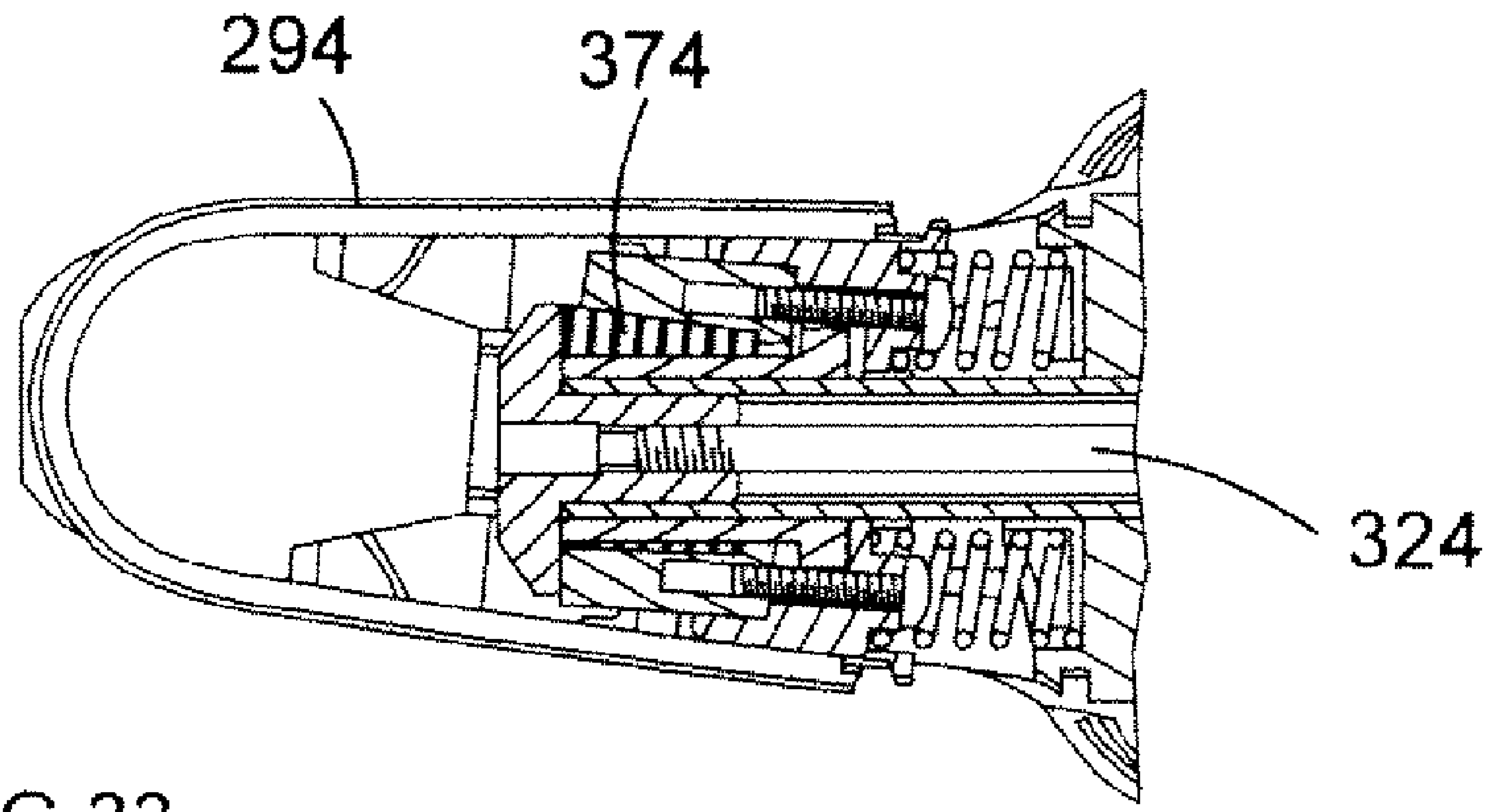


FIG.33

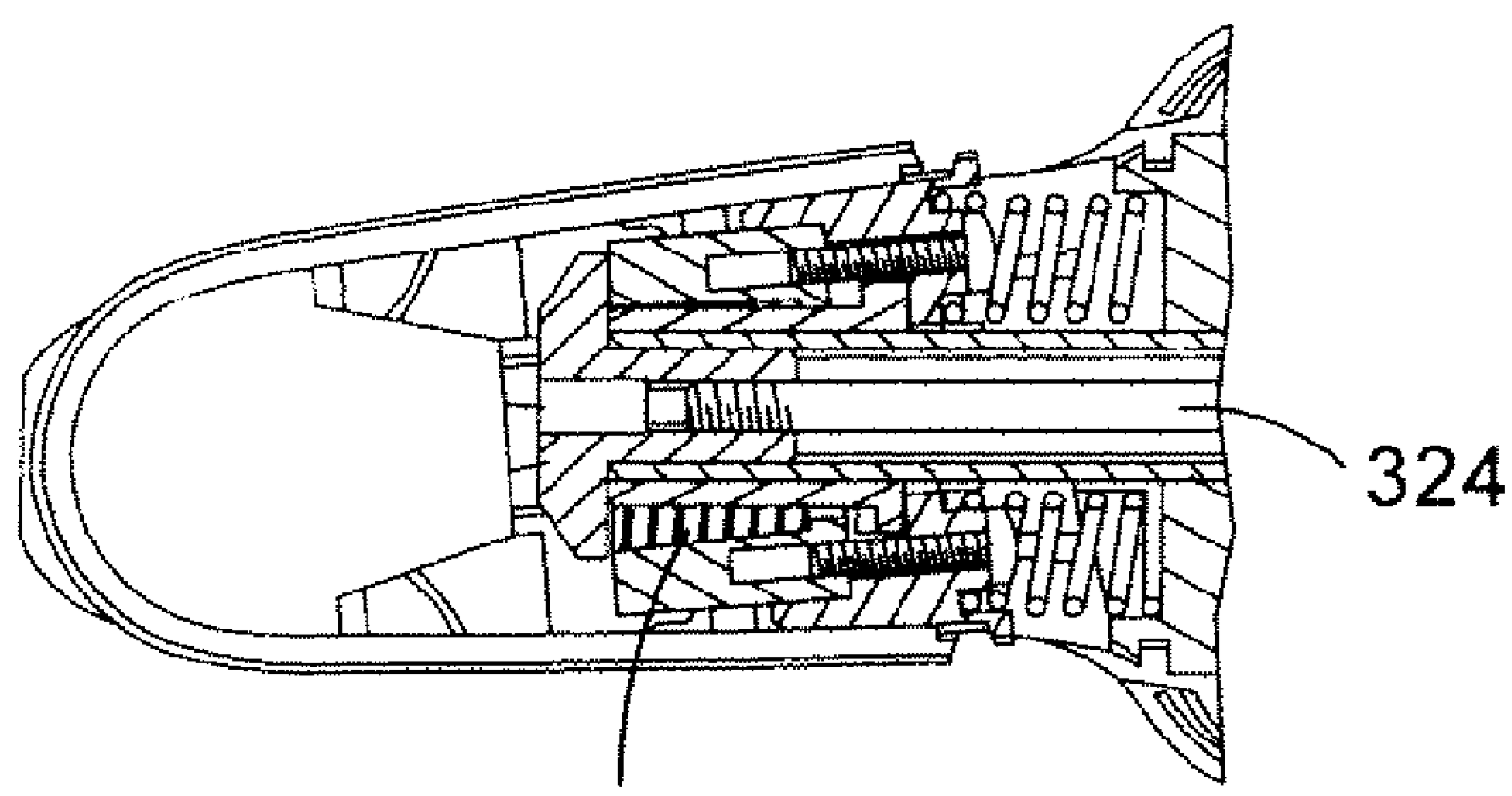
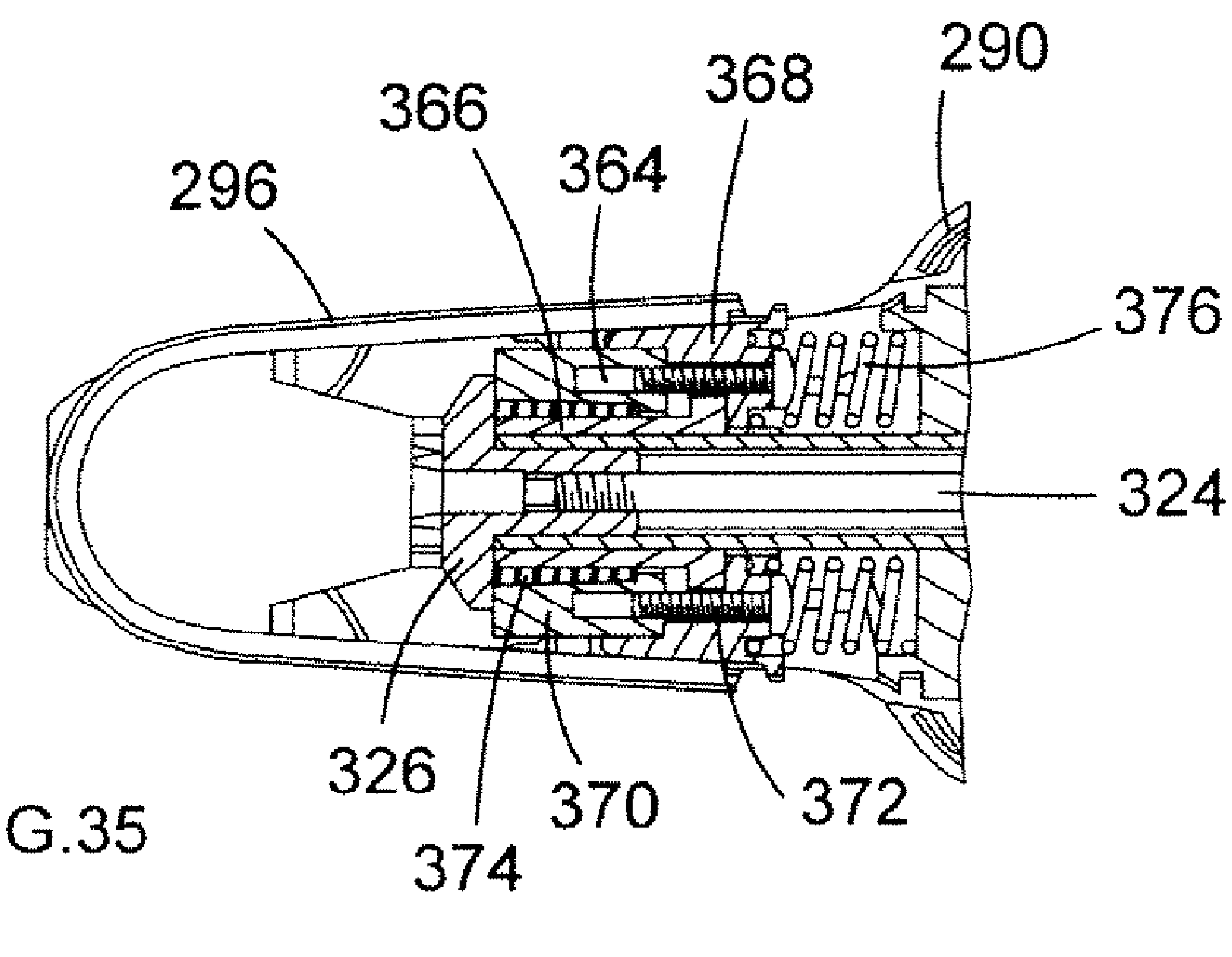


FIG.34



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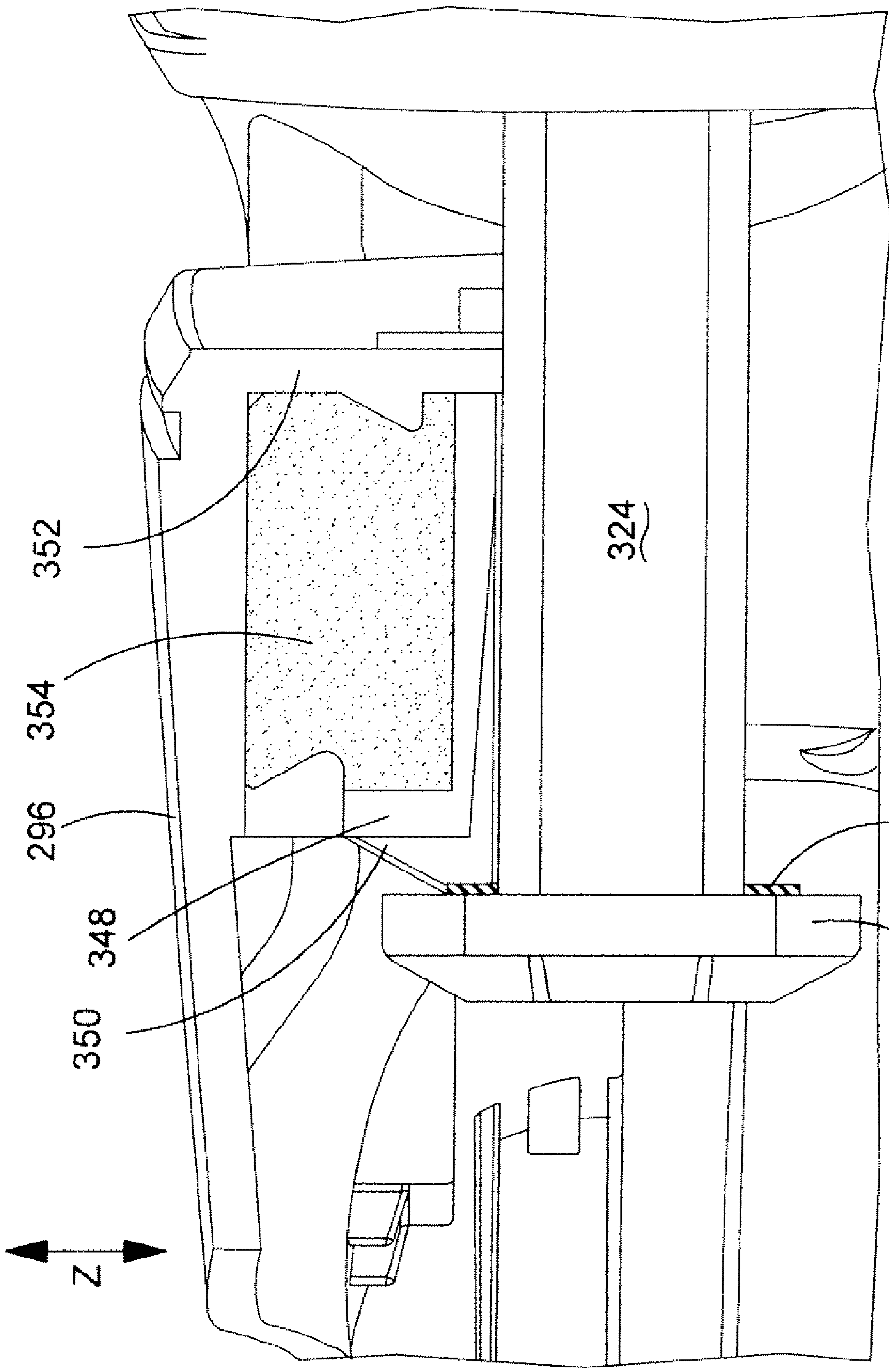

FIG.36

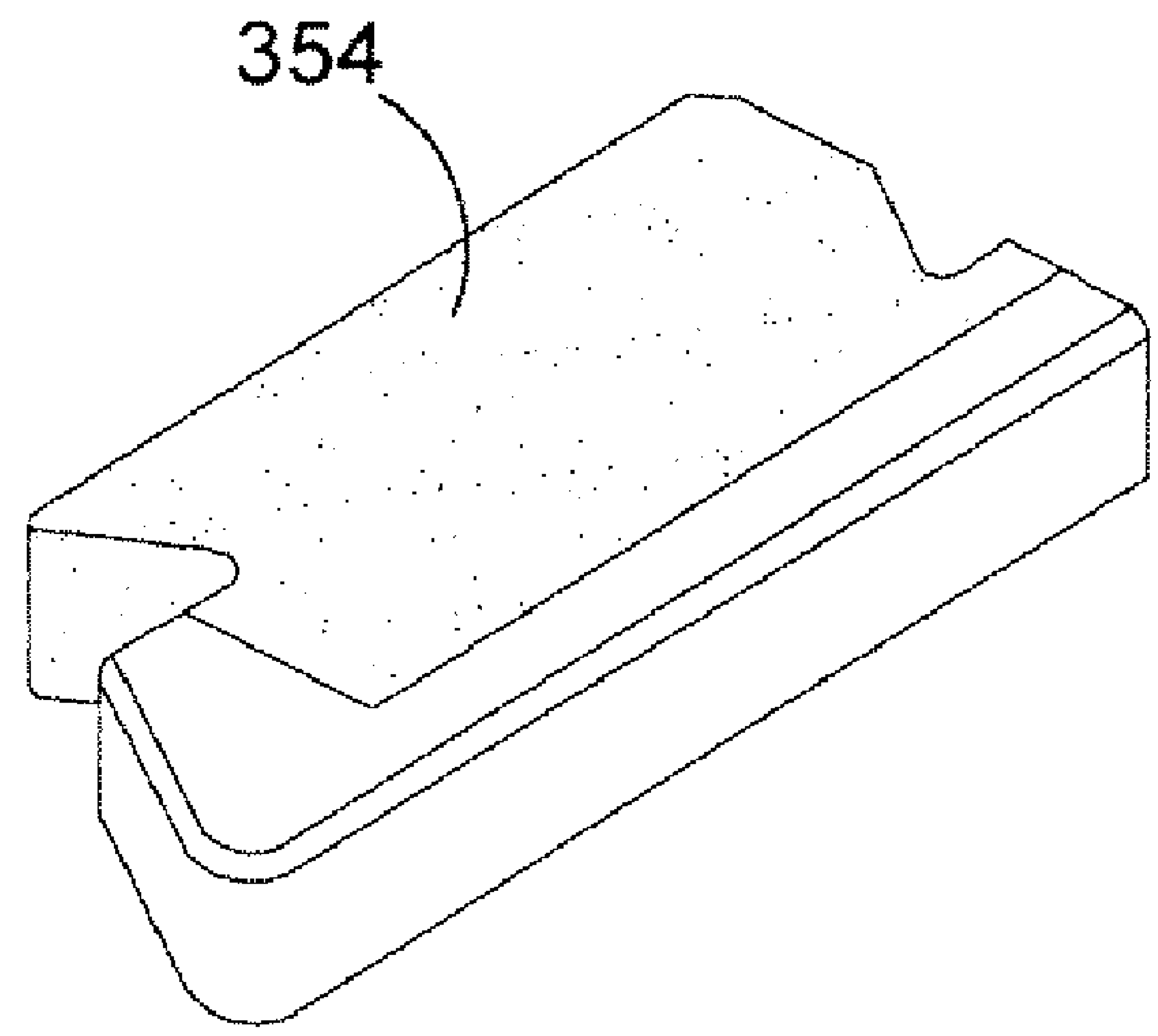

FIG.37

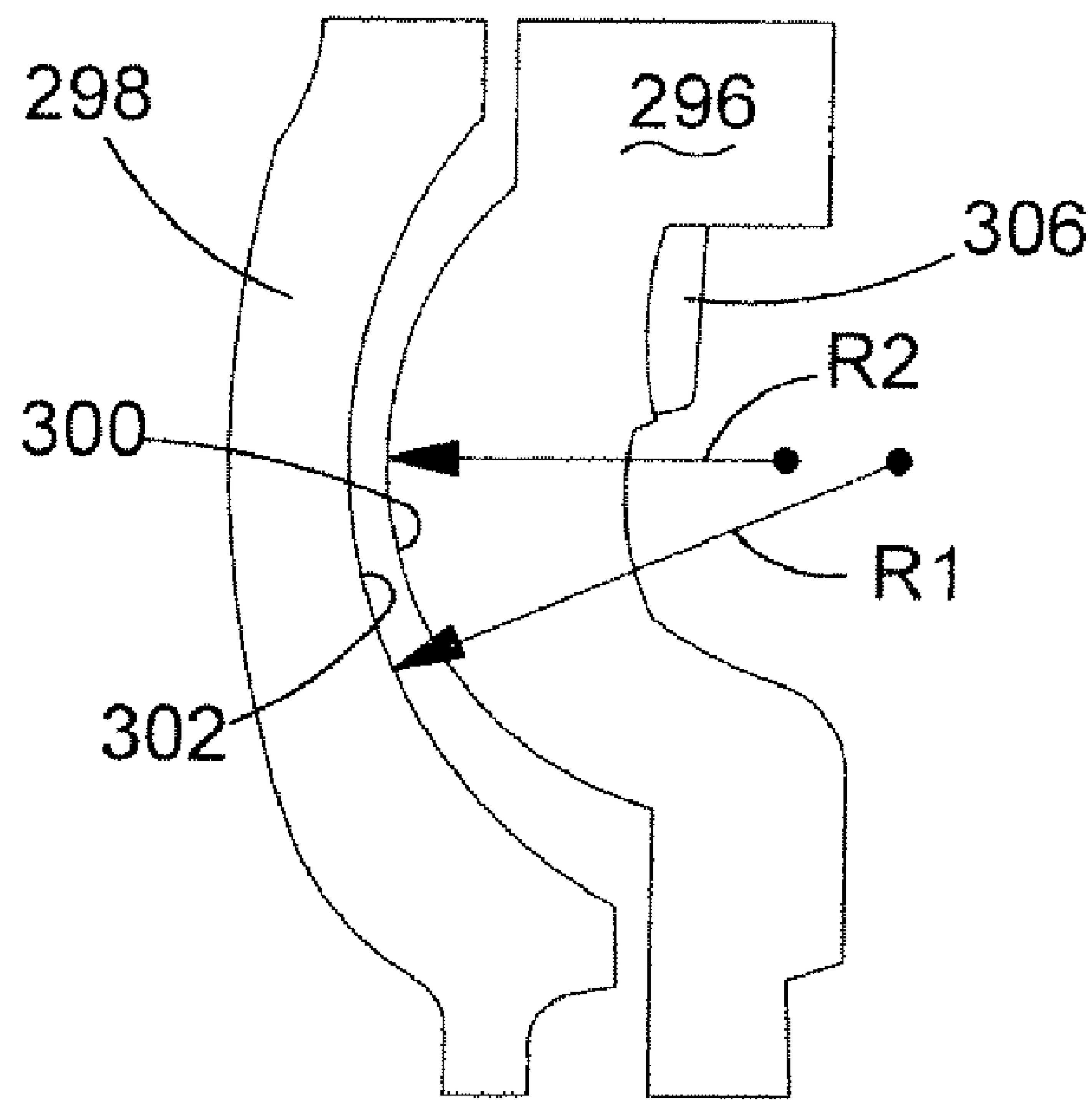

FIG.38

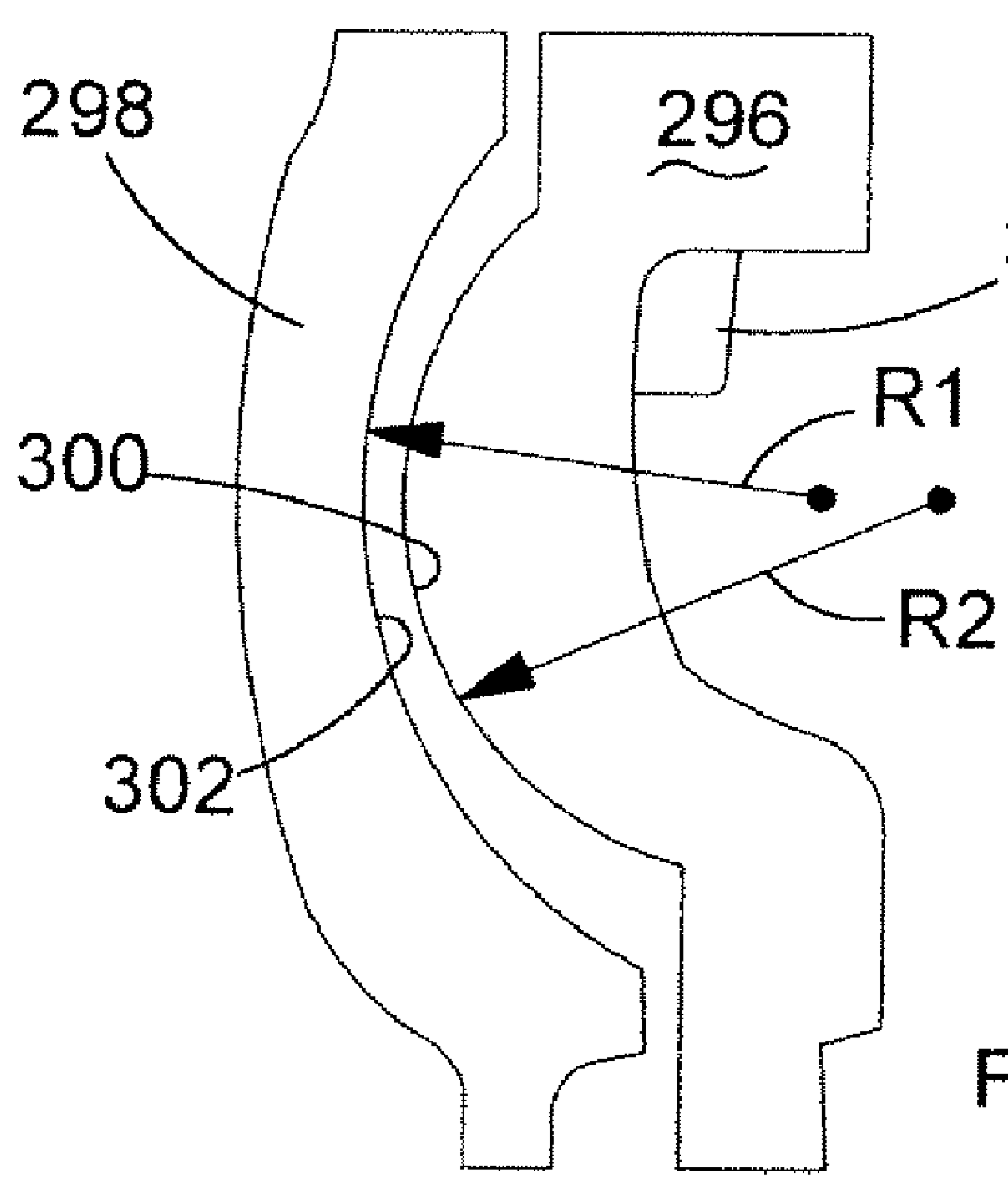

FIG.39

HANDLE FOR POWER TOOL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority, under 35 U.S.C. §119(a) (d), to UK Patent Application No. GB 08 013 13.8 filed Jan. 24, 2008, the contents thereof to be incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to a handle for a power tool.

BACKGROUND OF THE INVENTION

A hammer drill is disclosed in U.S. Pat. No. 4,749,049 in which a handle of the hammer drill is moveably mounted to the main housing of the hammer drill and vibration damping members are placed between the handle and the housing to attenuate the transmission of vibrations from the hammer drill housing to a user's hand.

Preferred embodiments of the present invention seek to improve the damping of vibrations from the main housing of power tools to handles thereof compared with known arrangements.

BRIEF SUMMARY OF THE INVENTION

Accordingly, there is provided a handle housing for a handle for a power tool, the handle housing comprising:—

a first housing part; and

a second housing part adapted to be mounted to the first housing part and subjected to a bending stress when mounted to said first housing part, the said first and second housing parts defining a chamber for accommodating one or more components of the power tool.

By providing a second housing part which is subjected to bending stress when mounted to the first housing part, this provides the advantage of minimising the extent to which vibrations generated in the power tool and transmitted to a handle of the tool cause the second housing part to vibrate, by creating a vibration damping bending stress which ideally is distributed substantially across the entire second housing part.

In a preferred embodiment, the first housing part has a first engaging portion, the second housing part has a second engaging portion adapted to engage said first engaging portion, and at least part of said second engaging portion has a larger radius of curvature than the corresponding part of said first engaging portion when not subjected to bending stress. However, it will be appreciated that a bending stress can be created by the second engaging portion having a smaller radius of curvature than the corresponding part of said first engaging portion

According to a further aspect of the present invention, there is provided a power tool comprising a handle having a handle housing as defined above.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:—

FIG. **1** is a perspective view of a hammer drill embodying the present invention;

FIG. **2** is a perspective view of a transmission housing of the hammer drill of FIG. **1**;

FIG. **3** is a perspective view from below of a speed adjustment dial and speed control mechanism of the hammer drill of FIG. **1**;

FIG. **4** is a view from below of the speed adjustment dial and speed adjustment mechanism of FIG. **3**;

FIG. **5** is a schematic view of a clamshell of an outer housing of a hammer drill having an alternative embodiment of a vibration damping mechanism to that of the hammer drill of FIG. **1**;

FIG. **6** is a schematic view of an alternative embodiment of transmission housing for use with the clamshell of FIG. **5**;

FIG. **7** is an exploded perspective view of a first embodiment of a side handle assembly for use with the hammer drill of FIG. **1**;

FIG. **8** is a vertical cross sectional view of the handle assembly of FIG. **7** mounted to the housing of the hammer drill of FIG. **1**;

FIG. **9** is a horizontal cross sectional view of the handle assembly of FIG. **7**;

FIG. **10** is an end view of the handle assembly of FIG. **7**;

FIG. **11** is a sectional view along the line B-B in FIG. **8**;

FIG. **12** is a sectional view along the line C-C in FIG. **8**;

FIG. **13** is a partially cut away perspective view of the assembled handle assembly of FIG. **7**;

FIG. **14** is an exploded view of a handle assembly of a second embodiment of the side handle assembly;

FIG. **15** is an exploded view of a handle assembly of a third embodiment of the side handle assembly;

FIG. **16** is a side view of a handle assembly of a fourth embodiment of the side handle assembly;

FIG. **17** is a side cross sectional view of a known two torque overload clutch of the hammer drill of FIG. **1**;

FIG. **18** is an exploded view of the clutch of FIG. **17**;

FIG. **19** is a perspective view of a torque change mechanism for the clutch of FIG. **18**;

FIG. **20** is a side cross sectional view of a new design of overload clutch for use with the hammer drill of FIG. **1**;

FIG. **21** is a side cross sectional view of a front part of a hammer drill;

FIG. **22** is an exploded perspective view of a hammer drill of a further embodiment of the present invention;

FIG. **23** is a detailed perspective cut away view of an upper part of the handle and housing of the hammer drill of FIG. **22**;

FIG. **24** is a detailed perspective cut away view of a lower part of the handle and housing of FIG. **22**;

FIG. **25** is a schematic view of the pivot pin and deformable member of the lower part of the handle and housing of FIG. **24** in a relaxed state;

FIG. **26** is a schematic view, corresponding to FIG. **25** of the lower parts of the housing when force is applied to the handle of the tool during use;

FIG. **27** is a perspective view of a bellows for use in the hammer drill of FIG. **22**;

FIG. **28** is a side view of the bellows of FIG. **27**;

FIG. **29** is an end view of the bellows of FIG. **27**;

FIG. **30** is a partially cut away perspective view of a first embodiment of a vibration damping member and sliding bar of the hammer drill of FIG. **22**;

FIG. **31** is a perspective side view of the vibration damping member and sliding bar of FIG. **30**;

FIG. **32** is a side cross sectional view of the vibration damping member and sliding bar of FIG. **30**;

FIG. **33** is a cross sectional plan view of a further embodiment of the tool handle and part of the tool housing of the hammer drill of FIG. **22** when twisted towards one direction;

FIG. **34** is a view corresponding to FIG. **33** when twisted towards the opposite direction to FIG. **33**;

FIG. **35** is a view corresponding to FIG. **33** when in an untwisted state;

FIG. **36** is a schematic view of a further embodiment of a vibration damping member and sliding bar of the hammer drill of FIG. **22**;

FIG. **37** is a schematic view of a compressible vibration damping member of FIG. **36**;

FIG. **38** is schematic view of the rear handle shown in FIG. **22**;

FIG. **39** shows a schematic view of an alternative design of rear handle to that shown in FIG. **38**.

DETAILED DESCRIPTION OF THE INVENTION

Speed Adjustment Mechanism

Referring to FIG. **1**, a hammer drill **2** has a main housing **4** defining a rear handle **6** for gripping by a user. The rear handle **6** is provided with a trigger switch **8** for supplying electrical power from a power cable **10** to a motor **12** mounted to a lower part of a transmission housing **14**, as shown in FIG. **2**. The transmission housing **14** is movably mounted in the main housing **41** for reasons which will be described in greater detail below.

The motor **12** drives a spindle **16** for rotating a drill bit (not shown) mounted to a chuck **18** at a forward part of the main housing **4**, and for driving a hammer mechanism **20** for imparting impacts to the drill bit. The operation of the spindle drive mechanism and hammer mechanism **20** will be familiar to persons skilled in the art and will not be described in greater detail herein.

The speed of rotation of the motor **12**, and therefore the hammer frequency and speed of rotation of the spindle **16**, are adjusted by rotation of a speed adjustment dial **22** rotatably mounted to an upper part of the main housing **4**. As shown in greater detail in FIG. **3**.

Referring to FIG. **3**, the speed adjustment dial **22** is mounted to a speed adjustment mechanism **24** having a support **26**, a first toothed gear **28** connected coaxially with the speed adjustment dial **22** for rotation therewith, and a second toothed gear **30** having an output shaft **32** having a non-circular transverse cross section in order to transfer torque from the speed adjustment dial **22** to an input of a potentiometer **34**, which in turn is connected to a control circuit (not shown) for controlling the speed of rotation of the motor **12**. Accordingly, by adjusting the speed control dial **22**, the speed of rotation of the motor **12** can be adjusted, which in turn enables the hammer frequency and speed of rotation of the **16** spindle to be adjusted.

The support **26** is adapted to be mounted to a component (not shown) in the main housing **4** which serves to support the motor control circuit. The support **26** is formed from durable, resilient plastics material, and comprises a first limb **36**, to which the first toothed gear **28** is attached, and a second limb **38**, to which the second toothed gear **30** is attached. The first and second limbs **36**, **38** are separated by an elongate aperture **40** so that limited flexing of the first and second limbs **36**, **38** is possible (independently of each other) to enable limited movement of the first toothed gear **28** relative to the second toothed gear **30**. The support **26** also comprises deformable mounting portions **42**, **44** for enabling the support **26** to be resiliently mounted to the component supporting the motor control circuit, which enables easy assembly of the hammer drill **2**.

The first toothed gear **28** is mounted coaxially with the speed adjustment dial **22** for rotation therewith, and meshingly engages the second toothed gear **30** such that rotation of the speed adjustment dial **22** causes rotation of the second toothed gear **30**, which in turn transfers torque to the potentiometer **34**, to adjust the variable resistance of the potentiometer **34** to adjust the motor speed. As shown in FIG. **3**, the second toothed gear **30** is longer than the first toothed gear **28** in the direction of its axis of rotation, such that the first and second toothed gears **28**, **30** remain in meshing arrangement with each other even while movement of the first toothed gear **28** relative to the second toothed gear **30** occurs as a result of relative flexing of the first and second limbs **36**, **38** of the support **26**.

If the user should drop the hammer drill **2** such that it lands on the speed adjustment dial **22** and an impact is transferred from the speed adjustment dial **22** to the first toothed gear **28**. The first limb **36** of the support **26** can flex to a limited extent relative to the second limb **38**. This enables limited movement of the first toothed gear **28** relative to the second toothed gear **38**. As the length of the second toothed gear **30** is longer than that of the first toothed gear **28**, the first toothed gear **28** slides along the second toothed gear **30** whilst remaining in meshing engagement with the second toothed gear **30** and without the first toothed gear **28** causing the second toothed gear **30** to move. In this way, the extent to which the impact imparted to the speed control dial **22** is transferred to the second toothed gear **30** is limited, which in turn limits the extent to which the impact is transferred to the potentiometer **34** and motor speed adjustment circuit. Accordingly, even if the impact is so great that the support **26** and/or speed adjustment dial **22** become damaged, the risk of damage to the potentiometer **34** and speed control circuit is minimised, and the speed adjustment mechanism **24** can be replaced.

The first and second toothed gears **28**, **30** are provided with indicators **46**, **48** respectively, which are in the form of arrows which, when aligned with each other so that the arrows point to each other, correspond to a predetermined orientation of the output shaft of the second toothed gear **30**. This enables the speed adjustment mechanism **24** to be assembled correctly as the gears **28**, **30** must be meshingly engaged with each other so that the indicators are capable of being aligned with each other and aids in mounting the speed control mechanism **24** to the hammer drill **2** during the manufacture or repair of the hammer drill **2**, since this orientation corresponds to the output shaft **32** of the second toothed gear **30** being aligned with a predetermined orientation of the input aperture of the potentiometer **34**.

Damping of Internal Transmission

Referring again to FIGS. **1** and **2**, the transmission housing **14** is moveably suspended inside the main housing **4** by means of two pairs of rigid pivotable arms **50**, **52** to damp the transmission of vibrations from the transmission housing **14** to the outer housing **4**. As a result of the weight of the motor **12** and its location below the rotational axis **54** of the spindle **16** of the drill **2**, the centre of mass of the transmission housing **14** is below the rotational axis **54** of the spindle **16**. As a result, because vibrations are predominantly produced as a result of impacts of the hammer mechanism **20** along the axis **54** of the spindle **16** (in the direction of arrow X in FIG. **2**), the transmission housing **14** tends to oscillate in a rotary manner about its centre of mass when vibrations propagate along the spindle **16**. This causes vibrations having a vertical component, i.e. in the direction of arrow Y in FIG. **2**.

The first pair of arms **50** is attached to opposed sides of the motor **12** at co-axial pivot points **56** and is attached to the outer housing **4** at co-axial pivot points **58** located near to the bottom of the handle **6**. The second pair of arms **52** is attached to opposed sides of the transmission housing **14** at co-axial pivot points **60** and is attached to the outer housing **4** at co-axial pivot points **62** located at the bottom of a central region **64** of the outer housing **4**. A pair of torsional springs **66** biases the transmission housing **14** forwards to counteract forces generated by the user leaning against the handle **6** and outer housing **4** when the hammer drill **2** is in use.

The length of the pivot arms **50**, **52** and the location of the corresponding pivot axes **56**, **58**, **60**, **62** are chosen to determine the path of travel of the transmission housing **14** relative to the outer housing **4**. The direction of travel of the transmission housing **14** will change as it moves within the outer housing **4**, the direction being substantially along the axis **54** of the spindle **16** in its foremost position and inclined relative to the axis **54** in its rearmost position.

In the early stages of drilling a hole in a workpiece (not shown), the user is concentrating on directing the tip of the tool bit (not shown), and therefore does not lean hard against the outer housing **4** of the tool **2**, so as to prevent the tip of the bit from wandering. As a result, vibrations in the direction of arrow X in FIG. **2** (i.e. along the axis **54** of the spindle **16**) are minimal, and vibrations in the direction of arrow Y in FIG. **2** are almost non-existent. The direction of relative motion of the transmission housing **14** relative to the outer housing **4** should therefore be along the spindle axis **54**. During the early stages, the transmission housing **14** will be in its foremost position. When it is in its foremost position, the direction of movement of the transmission housing **14** is substantially in the direction of arrow X. The torsional springs **66** are relaxed and the transmission housing **14** is near its foremost position within the outer housing **4**.

As drilling of the hole progresses, the user begins to lean harder against the tool bit. As the user exerts more pressure, the transmission housing **14** and motor **12** move rearwardly within the outer housing **4** against the biasing force of the springs **66**. Furthermore, the rearward vibrations along the spindle axis **54** increase in reaction to the hammer action. This causes the transmission housing **14** to oscillate about its centre of mass, which in turn creates vibrations having a significant component in the direction of arrow Y in FIG. **2**. The torsional springs **66** are under more tension than when the transmission housing **14** is at its foremost position, and the transmission housing **14** is near its rearmost position within the outer housing **4**. The direction of travel at this stage has alter and is inclined relative to the longitudinal axis **54** of the spindle **16**; as a result of which movement of the transmission housing **14** relative to the outer housing **4** clamps vibrations in the directions of arrows X and Y in FIG. **2**.

A laterally oriented arm **68** connecting the rear of the transmission housing **14** to the outer housing **4** enables damping of movement in a direction orthogonal to the arrows X and Y (i.e. in the direction of arrow Z in FIG. **2**) to occur. This damps vibrations caused by the twisting moment of rotation of the spindle **16** when encountering obstacles in the workpiece (not shown).

An alternative embodiment of a vibration damping mechanism is shown schematically in FIGS. **5** and **6**. The rigid pivoting arms **50**, **52** are replaced by a pair of profiled cam grooves **70**, **72** formed in an inner surface of the outer housing **4**, which receive respective cam followers in the form of rollers **74**, **76** rotatable mounted on each side of the transmission housing **14**. The transmission housing **14** is biased by means of springs (not shown) towards its foremost position relative to the outer housing **4**, in a manner similar to the embodiment of FIGS. **1** and **2**. The profile of the cam grooves **70**, **72** is chosen such that as a user applies force to the outer housing **4** while drilling a hole, the rollers **74**, **76** move along the cam grooves **70**, **72** respectively to adjust the orientation of the transmission housing **14** relative to the outer housing **4** so that the direction of relative motion of the transmission housing **14** relative to the outer housing **4** can be closely matched to the resultant direction of vibrations transmitted from the transmission housing **14** to the outer housing **4**.

Side Handle Assembly

Referring to FIGS. **7** to **13**, a handle assembly **78** for attachment to the hammer drill **2** of FIG. **1** has a support in the form of a base **80** of durable plastics material, a mounting part comprising a flexible strip **82** of metal for mounting the handle assembly **78** to a forward part of the outer housing **4**, and a handle **84** of suitable resilient material for gripping by a user.

The base **80** has a part-circular portion **86** for abutting the side of a front part of the outer housing **4** of the hammer drill **2**, and a socket **88** formed at its upper side for location of a depth stop mechanism (not shown), the function of which will be familiar to persons skilled in the art, and will therefore not be described in further detail herein. A generally circular platform **90** is formed on one side of the base **80**, and is provided with a hole **92** for receiving a threaded rod **94** connected to the two ends **96**, **98** of the metal strip **82** which is formed into a loop.

A support **100** of durable plastics material is mounted to the platform **90** and has a recess **102** of hexagonal shape for receiving a hexagonal head **104** of an elongate metal bolt **106** so that the bolt **106** is prevented from rotating relative to the support **100**. A hole **108** is formed through a base **110** of the recess **102** for alignment with the hole **92** in the platform **90** in order to receive the threaded rod **94**. An axial threaded internal passage **112** (FIG. **8**) is provided in the elongate bolt **106** to enable the threaded rod **94** to be screwed into the threaded passage **112**, the entrance to the passage **112** being provided in the head **104** of the bolt **106** facing the support **100**.

The end **114** of the threaded rod **94** facing away from the platform **90** is connected to the two ends **96**, **98** of the metal strip **82**, which is formed into a loop, such that the metal strip **82** can be loosely wrapped around the front part of the outer housing **4** of the hammer drill **2**. The metal strip **82** is prevented by the housing **4** from rotating relative to the base **80**, as a result of which the threaded rod **94** is prevented from rotating relative to the base **80**. As a result, rotation of the elongate bolt **106** relative to the base **80** causes the threaded rod **94** to move axially relative to the tubular passage **112** in the elongate bolt **106**, to either draw the threaded rod **94** through the holes **92**, **108** in the platform **90** and support **100** into the threaded rod **106** to tighten the metal strip **82** around the outer housing **4**, or to cause the threaded rod **94** to move out of the passage **112** to loosen the metal strip **82** around the housing **4**. The support **100** is located in position by being sandwiched between the head **104** of the elongate bolt **106** and the platform **90** on the base **80**.

The handle **84** is formed from durable plastics material and is rotatably mounted to the shank **116** of the elongate bolt **106** by means of two resilient rubber dampers **118**, **120**. The first damper **118** is mounted on the shank **116** of the bolt **106** adjacent the head **104**, and the second damper **120** is mounted on the shank **116** of the bolt **106** at the end **122** of the shank **116** remote from the head **104**. The dampers **118**, **120** are non-rotatably mounted to the handle **84** by means of grooves **124**, **126** formed on the outer surface of the dampers **118**, **120** respectively, which engage respective ridges **128**, **130** (FIGS. **11** and **12**) on the inside of the handle **84**. The first damper **118** is held in place by being sandwiched between the support **100** and the head **104** of the bolt **106** on one side, and the ridges **128** on the other side. The second damper **120** is held in place by being sandwiched between a nut **132** and washer **134** screwed onto the end **122** of the shank **116** of the bolt **106** and the ridges. **130** on the internal surface of the handle **84**. Limited axial movement of the handle **84** relative to the bolt **106** is possible as a result of compression of the dampers **118**, **120**, as is limited pivoting of the handle **84** about an axis perpendicular to the longitudinal axis of the bolt **106**.

The handle **84** is provided with a radially extending flange **136** formed at its end adjacent the support **100**. The flange **136** is provided with a pair of recesses **138** (FIG. **13**) located on diametrically opposite sides of the longitudinal axis of the handle **84**. A locking ring **140** of durable plastics material is sandwiched between the flange **136** and the support **100**. The locking ring **140** is provided with a pair of diametrically opposite first pegs **142** on a first face **144** for location in the respective recesses **138** in the flange **136**, the circumferential extent of the pegs **142** being less than that of the recesses **138** in the flange **136** to allow limited pivoting movement around the longitudinal axis of the bolt **106** of the handle **84** relative to the locking ring **140**.

The locking ring **140** is also provided with a pair of diametrically opposite second pegs **146** located on a second face **148** of the locking ring **140**, opposite to the first pegs **142**. The second pegs **146** are offset by generally **90** degrees relative to the first pegs **142** and engage a pair of recesses **150** formed on diametrically opposite sides of the plastic support **100**. The circumferential extent of the second pegs **146** is less than that of the recesses **150** to permit limited pivotal movement of the locking ring **140** around the longitudinal axis of the bolt **106** relative to the support **100**. Springs (not shown) can be provided (though not required) in the recesses **138** on the flange **136** and/or in the recesses **150** in the support **100** to bias the first and second pegs **142**, **146** towards the centre of the corresponding recesses **138**, **150** respectively.

It can therefore be seen that limited rotation of the handle **84** relative to the base **80** is possible, but beyond predetermined limits, torque is transmitted from the handle **84** via the locking ring **140** to the support **100**, which in turn causes rotation of the elongate bolt **106** relative to the threaded rod **94** to either tighten or loosen the metal strip **82** around the outer housing **4** of the hammer drill **2**.

A second embodiment of a side handle assembly embodying the present invention is shown in FIG. **14**, in which pairs of resilient vibration damping members **152** are provided in the recesses **150** in the support **100**. Similar vibration damping members (not shown) can be provided in the recesses **138** on the flange **136** of the handle **84**.

A third embodiment of a side handle assembly embodying the present invention is shown in FIG. **15**, in which pairs of resilient vibration damping members **154** are provided on the first and second pegs **142**, **146** on the locking ring **140**.

A fourth embodiment of a side handle assembly embodying the present invention is shown in FIG. **16**, in which a strip **156** of resilient material is provided on the inner surface of the metal strip **82**, in order to damp vibrations transmitted from the outer housing **4** of the hammer drill **2** to the metal strip **82**.

Overload Clutch Assembly

A known two torque clutch connected between a motor output shaft and a spindle drive of the hammer drill of FIG. **1** is disclosed in WO 2004/024398. A similar clutch will now be described in more detail with reference to FIGS. **17** to **19**.

A bevel gear **158** which forms part of the clutch arrangement is integrally formed with a shaft **160** of circular cross section. The upper end of the shaft **160** is rotatably mounted within the housing **4** of the hammer via a bearing comprising an inner race **162** which is rigidly attached to the shaft **160**, an outer race **164** which is rigidly attached to the housing and ball bearings **166** which allow the outer race **164** to freely rotate about the inner race **162**. The bearing is located adjacent the underside of the bevel gear **158**.

A driving gear **168** connected to an output shaft of the motor **12** is rotatably mounted on the shaft **160** and can freely rotate about the shaft **160**. The driving gear **168** abuts the underside of the inner race **162** of the bearing and is prevented from axially sliding away from (downwardly) by the rest of the clutch mechanism which is described in more detail below.

The driving gear **168** is so shaped that it surrounds a toroidal space, the space being surrounded by a flat bottom **170** which projects radially outwards from the shaft **162**, an outer side wall **172** upon the outer surface of which are formed the teeth of the driving gear **168** and an inner side wall **174** which is adjacent the shaft **160**.

Located within the toroidal space of the driving gear **168** adjacent the flat bottom **170** is a washer **176** which surrounds the inner wall **174** and shaft **160**. Mounted on top of the washer **176** is belleville washer **178**. The inner edge of the belleville washer **178** is located under the inner race **162** of the bearing whilst the outer edge of the belleville washer **178** abuts against the outer edge of the washer **176** adjacent the outer wall **172** of the driving gear **168**. The driving gear **168** is held axially on the longitudinal axis of the shaft **160** in relation to the belleville washer **178** so that the belleville washer **178** is compressed causing it to impart a downward biasing force onto the washer **176** towards the flat bottom **170** of the driving gear **168**.

Formed in the flat bottom **170** of the driving gear **168** are two sets of holes; a first inner set **180** of five, each located equidistantly from the longitudinally axis of the shaft **160** in a radial direction and angularly from each other around the longitudinal axis of the shaft **160**; a second outer set **182** of five, each located equidistantly from the longitudinal axis of the shaft **160** in a radial direction and angularly from each other around the longitudinal axis of the shaft **160**. The radial distance of the outer set **182** from the longitudinal axis of the shaft **160** is greater than that of the inner set **180**.

A ball bearing **184** is located in each of the holes **180**, **182** and abuts against the underside of the washer **176**. The diameters of all the ball bearings **184** are the same, the diameter being greater than the thickness of the flat bottom **170** of the driving gear **168** thereby resulting either the top or bottom of the ball bearings **184** protruding beyond the upper or lower surfaces of the flat bottom **170** of the driving gear **168**.

Mounted on the shaft **160** below and adjacent to the driving gear **168** is a first slip washer **186**. The first slip washer **186** comprises a circular hole with two splines **188** projecting into the hole which, when the washer **186** is mounted on the shaft **160**, locate within two corresponding slots **190** formed in the shaft **160**. As such, the first slip washer **186** is non-rotatably mounted on the shaft **160**, the shaft **160** rotating when the first slip washer **186** rotates.

Formed on one side of the first slip washer **186** around the periphery is a circular trough **192** with a U shaped cross section. The circular trough **192** is separated into five sections, the depth of each section of trough varying from a low point to high point. Each section of trough is the same in shape as the other sections of trough. The low point of one section of trough is adjacent to the high point of the next section. The two are connected via a ramp. When the slip washer **186** is mounted on the shaft **160**, the side of the first slip washer **186** faces the driving gear **168**. The diameter of the first slip washer **186** is less than that of the driving gear **168** and is such that, when the slip washer **186** is mounted on the shaft **160**, the trough **192** faces the inner set of holes **180**. The five sections which form the trough **192** correspond to the five holes **180** which formed the innermost set of holes in the driving gear **168** so that, when the clutch is assembled, one ball bearing **184** locates in each section of the trough **192**.

Mounted on the spindle shaft **160** below the first slip washer **186** is a second slip washer **194**. The second slip washer **194** is dish shaped having an angled side wall **196** surrounding a flat base **198**. When mounted on the shaft **160**, the first slip washer **186** locates within the space surrounded by the side wall **196** and the flat base **198** surface as best seen in FIG. **17**. The second slip washer **194** can freely rotate about the spindle shaft **160**. A rectangular slot **200** superimposed on a circular hole is formed in the flat base **198** symmetrical about the axis of rotation of the second slip washer **194**. Formed on the top of the angled side wall **196** is a flange **202** which projects radially outwards.

Formed on the top side of the radial flange **202**, around the radial flange **202**, is a circular trough (not shown) with a U shaped cross section which is similar in shape to that on the first slip washer **186**. The circular trough is separated into five sections, the depth of each section of trough varying from a low point to a high point. Each section of the trough is the same in shape as the other sections of trough. The low point of one section of trough is adjacent to the high point of the next section. The two are connected via a ramp. When the second slip washer **194** is mounted on the shaft **160** as shown, the side of the flange **202** with the trough faces the driving gear **168**. The diameter of the flange **202** is such that, when the second slip washer **194** is mounted on the shaft **160**, the trough faces the outer set of holes **182** in the driving gear **168**. The five sections which form the trough correspond to the five holes **182** which form the outermost set of holes in the driving gear **168** so that, when the clutch is assembled, one ball bearing **184** locates in each section of the trough.

The size of the ramps in the trough **192** of the first slip washer **186** is less than that of the size of the ramps formed in the trough of the second slip washer **194**, the variation of the height of each section of trough in the first slip washer **186** from the low end to the high end being less than that of the variation of the height of each section of trough in the second slip washer **194** from the low end to the high end.

When the clutch is assembled, the ball bearings **184** in the innermost set of holes **180** in the driving gear **168** locate within the trough **192** of the first slip washer **186** (one ball bearing per section) and the ball bearings **184** in the outer most set of holes **182** in the driving gear **168** locate within the trough of the second slip washer **194** (one ball bearing per section).

A circular clip **204** is rigidly mounted on the shaft **160** below the second slip washer **194** which holds the first and second slip washers **186**, **194** together with the driving gear **168** against the underside of the bearing in a sandwich construction preventing axial displacement of the three along the shaft **160**. Rotation of the circular clip **204** results in rotation of the shaft **160**.

The lower end of shaft **160** is rotatably mounted within the housing **4** of the hammer via a second bearing comprising an inner race **206** which is rigidly attached to the shaft **160**, an outer race **208** which is rigidly attached to the housing **4** and ball bearings **210** which allow the outer race **208** to freely rotate about the inner race **206**. The bearing is located adjacent the underside of the circular clip **204**.

When the clutch is fully assembled and no rotary torque is being transferred through it, each of the ball bearings in the innermost holes **180** of the driving gear **168** locate in the lowest points of the corresponding sections of the trough **192** in the first slip washer **186**. When the ball bearings **184** are located within the lowest points of the sections of the trough **192**, the tops of the ball bearings **184**, which are adjacent to the washer **176**, are flush with the surface facing the washer **176** of the flat bottom **170** of the driving gear **168**. The ball bearings **184** locate in the lowest points due to the biasing force of the belleville washer **178** which is biasing the washer **176** in a downward direction which in turn pushes the ball bearings **184** to their lowest positions.

Similarly, when the clutch is fully assembled and no rotary torque is being transferred through it, each of the ball bearings **184** in the outermost holes **182** of the driving gear **168** locate in the lowest points of the corresponding sections of the trough in the second slip washer **194**. When the ball bearings **184** are located within the lowest point of the sections of the trough, the tops of the ball bearings **184**, which are adjacent to the washer **176**, are flush with the surface of the flat bottom **170** of the driving gear **168** facing the washer **176**. The ball bearings **184** locate in the lowest points due to the biasing force of the belleville washer **178** which is biasing the washer **176** in a downward direction which in turn pushes the ball bearings **184** to their lowest positions.

Formed through the length of the shaft **160** is a tubular passageway **212**. Located within the lower section of the tubular passageway **212** is a rod **214**. The rod **214** projects below the shaft **160** beyond the shaft **160**. A seal **216** is attached to the base of the shaft **160** and surrounds the rod **214**. The seal **216** prevents the ingress of dirt.

Adjacent to the upper end of the rod **214** is a sleeve **218**. The end of the rod **214** is held against the sleeve **218** by a cam **228** which is described in more detail below. Projecting in opposite directions perpendicularly to the sleeve **218** are two pegs **220**. The sleeve **218** is located within the shaft **160** in a position along the length of the shaft **160** where the sleeve **218** and pegs **220** are surrounded by the circular clip **204**. Two vertical slots **222** are formed in the sides of the circular clip **204**. The top end of the slots **222** extends to the top of the circular clip **204**. The bottoms of the slots **222** extend part way down the circular clip **204**, terminating in a base. In each of the slots **222** is located one of the pegs **220**. The pegs **220** extend through the slots on the shaft **160** and the circular clip **204**. The rod **214**, together with the sleeve **218** and two pegs **220** can vertically slide up and down. The lowest position is where the two pegs **220** abut the bottom of the slots **222** of the circular clip **204**, further downward movement being prevented by the base of the slots **222** in the circular clip as shown in FIG. **17**. The highest position is where the two pegs **220** locate within the rectangular slot **200** within the second slip washer **194** in addition to being located within the top end of the slot **190**, further upward movement being prevented by the underside of the first slip washer **194**. A spring **224** locates between the top of the shaft **160** and the sleeve **218** in the upper section of the tubular passageway **212**. The spring **224** biases the sleeve **218**, two pegs **220** and rod **214** towards their lowest position. Regardless of whether the pegs **220** are at their upper or lower position, rotation of the pegs **220** results in rotation of the circular clip **204** due to the pegs **220** being located in the slots **222** which in turn results in rotation of the shaft **160**.

Movement of the rod **214** between its lowest and highest position changes the clutch from a low torque to a high torque clutch. The mechanism by which the rod **214** is moved vertically is described below. The clutch operates by transferring the rotary movement from the driving gear **168** to the bevel gear **158** which is integral with the shaft **160**. When the torque across the clutch is below a predetermined value the driving gear **168** will rotatingly drive the bevel gear **158**. When the torque across the clutch is above a predetermined value, the driving gear **168** will rotate but the bevel gear **158** will remain stationary, the clutch slipping as the driving gear **168** rotates. The predetermined value of the torque at which the clutch slips can be alternated between two preset values by the sliding movement of the rod **214** between the lowest and highest positions.

The mechanism by which the clutch works will now be described.

Low Torque Operation

The rod **214** is located in its lowest position when the clutch is acting as a low torque clutch. When in this position, the pegs **220** are disengaged from the rectangular aperture **200** in the second slip washer **194**. As such, therefore, the second slip washer **194** can freely rotate about the shaft **160**. As such no rotary movement can be transferred between the second slip washer **194** and the shaft **160**. Therefore, all rotary movement between the driving gear **168** and the bevel gear **158** is transferred via the first slip washer **186** only.

The electric motor **12** rotatingly drives the driving gear **168**, and the driving gear **168** can freely rotate about the shaft **160**. As such, no rotary movement can be transferred to the shaft **160** directly from the driving gear **168**. As the driving gear rotates, the ball bearings **184** located within the innermost set of holes **180** formed within the driving gear **168** also rotate with the driving gear **168**. Under normal circumstances when the rotary movement is being transferred, the ball bearings **184** are held in the lowest point of the section of the trough **192** formed in the first slip washer **186** by the washer **176** which is biased downwardly by the biasing force of the belleville washer **178**. The direction of rotation is such that the ball bearings **184** are pushed against the ramps of the trough **192**, the ball bearings **184** being prevented from riding up the ramps by the biasing force of the belleville washer **178**. As such, when the ball bearings **184** in the innermost set **180** rotate, the ramps and hence the first slip washer **186** also rotate. As the first slip washer **186** is non-rotatably mounted on the shaft **160** due to the splines **188** engaging the slot **190** in the shaft **160**, as the first slip washer **186** rotates, so does the shaft **160** and hence the bevel gear **158**. As such the rotary movement is transferred from the driving gear.**168** to the bevel gear **158** via the ball bearings **184** in the innermost set of holes **180**, the ramps and the first slip washer **186**.

However, when a torque is applied to the clutch (in the form of a resistance to the turning movement of the bevel gear **158**) above a certain amount, the amount of the force required to be transferred to from the ball bearings **184** to the ramps on the first slip washer **186** is greater than the force exerted by the belleville washer **178** on the ball bearings **184** keeping them in the lowest point of the section of the trough **192**. Therefore, the ball bearings **184** ride over the ramps and then continue down the slope of the next section until it engages the next ramp. If the torque is still greater than the predetermined amount the process is repeated, the ball bearing **184** riding up the ramps against the biasing force of the belleville washer **178** and then rolling across the next section. As this happens the first slip washer **186** remains stationary and hence the shaft **160** and bevel gear **158** also remain stationary. Therefore, the rotary movement of the driving gear **168** is not transferred to the bevel gear **158**.

Though the second slip washer **194** plays no part in transferring the rotary movement of the driving gear **168** to the shaft **160** in the low torque setting, it is nevertheless rotated by the driving gear **168**.

High Torque Operation

The rod **214** is located in its highest position when the clutch is acting as a high torque clutch. When in this position, the pegs **220** are engaged with the rectangular aperture **200** in the second slip washer **194**. As such, the second slip washer **194** is rotatably fixed to the shaft **160** via the pegs **220** located in the rectangular slot **200**, the slots **222**, **190** of the circular clip **204** and shaft **160**. As such rotary movement can be transferred between the second slip washer **194** and the shaft **160**. Therefore, rotary movement between the driving gear **168** and the bevel gear **158** can be transferred via the first slip washer **186** and/or the second slip washer **194**.

The mechanism by which the driving gear **168** transfers its rotary motion to the first slip washer **186** via the ball bearings **184** and ramps is the same as that for the second slip washer **194**.

The electric motor **12** rotatingly drives the driving gear **168** and the driving gear **168** can freely rotate about the shaft **160**. As such, no rotary movement can be transferred to the shaft **160** directly from the driving gear **168**. As the driving gear **168** rotates, the ball bearings **184** located within the innermost **180** and outermost **182** set of holes formed within the driving gear **168** also rotate with the driving gear **168**. Under normal circumstances when the rotary movement is being transferred, the ball bearings **184** are held in the lowest points of the sections of the troughs formed in both the first slip washer **186** and the second slip washer **194** by the washer **176** which is biased downwardly by the biasing force of the belleville washer **178**. The direction of rotation is such that the ball bearings **184** are pushed against the ramps of the troughs of both the first slip washer **186** and the second slip washer **194**, the ball bearings **184** being prevented from riding up the ramps by the biasing force of the belleville washer **178**. As such, when the ball bearings **184** rotate, the ramps and hence the first and second slip washers **186**, **194** also rotate. As both the first and second slip washers **186**, **194** are non-rotatably mounted on the shaft **160**, as the first and second slip washers **186**, **194** rotate, so does the shaft **160** and hence the bevel gear **158**. As such the rotary movement is transferred from the driving gear **168** to the bevel gear **158** via the ball bearings **184** in the inner and outermost set of holes **180**, **182**, the ramps and the first and second slip washers **186**, **194**.

However, when a torque is applied to the clutch (in the form of a resistance to the turn movement of the bevel gear **158**) above a certain amount, the amount of the force required to be transferred to from the ball bearings **184** to the ramps is greater than the force exerted by the belleville washer **178** on the ball bearings **184** keeping them in the lowest points of the sections of the troughs. The amount of torque required in the high torque setting is higher than that in the low torque setting. This is due to the size of the ramps between sections of the trough in the second slip washer **194** being greater than the size of the ramps between sections of the trough **192** in the first slip washer **186**, requiring the belleville washer **178** to be compressed to a greater extent and hence requiring force for it to be done so. Therefore, when the force exceeds this greater value, the ball bearings **184** ride over the ramps and then continue down the slope of the next section until they engage the next ramp. If the torque is still greater than the predetermined value the process is repeated, the ball bearings **184** riding up the ramps against the biasing force of the belleville washer **178** and then rolling across the next section. As this happens the first and second slip washers **186**, **194** remain stationary and hence the shaft **160** and bevel gear **158** also remain stationary. Therefore, the rotary movement of the driving gear **168** is not transferred to the bevel gear **158**.

Torque Change Mechanism

The mechanism by which the torque setting of the clutch is adjusted will now be described.

Referring to FIGS. **17** and **19**, the underside of the two torque clutch is enclosed within a clutch housing **226**. The rod

214 projects through the base of the housing 226. The lowest end of the rod 214 engages with a cam 228. The cam 228 is mounted on a shaft 230 which can pivot about its longitudinal axis 232. The rod 214 and hence the cam 228 are biased towards their lowest position by the spring 224 (FIG. 18) within the shaft 160 of the clutch. Pivotal movement of the shaft 230 results in a pivotal movement of the cam 228 which causes the end of the rod 214 slidably engaged with the cam 228 to ride up the cam 228 causing the rod 214 to slide vertically upwards against the biasing force of the spring 224 changing the clutch from the low torque to high torque setting.

Attached to shaft 230 is a flexible lever 234. Attached to the end of the flexible lever 234 is the cable 236 of a bowden cable 238. The pulling movement of the cable 236 pulls the lever 234 causing it and the shaft 230 to rotate about the axis 232. This results in the cam 228 pivoting which in turn moves the rod 214 vertically upwards. Release of the cable 236 allows the lever 234 and shaft 230 to pivot, allowing the cam 228 to move to its lowest position due to the biasing force of the spring 224 via the rod 214. The flexible lever 234 is sufficiently stiff to be able to move the shaft 230 and hence the cam 228 to change the torque setting of the clutch. However, if the two pegs 220 are not aligned with rectangular aperture on the second slip washer 194, the pegs 220 and hence the rod 214 is prevented from travelling to their uppermost position. However, the means by which the cable 236 is pulled will not be able to discern this. Therefore, in this situation, the lever 234 bends allowing the pegs 220 to abut the underside of the second slip washer 194 whilst allowing the cable 236 to be pulled by its maximum amount. When the motor 12 is energised, the second slip washer 194 will rotate, aligning the pegs 220 with the rectangular hole in the second slip washer 194, at which point the pegs 220 enter the rectangular hole due to the biasing force of the bent lever 234.

Low Wear Torque Change Shaft Bearing

Referring to FIG. 20, a new design of clutch is described. The main difference to the design of the clutch previously described with reference to FIGS. 17 to 19 is the use of a ball bearing 242 sandwiched between the end of the shaft 214 and the sleeve 218. Where the same features are present, the same reference numbers are used. The shaft 214 extends into a tubular bearing housing 240 having an inner chamber 243 of circular cross section and in which is located a ball bearing 242 which is sandwiched between the end of the shaft 214 and the sleeve 218 and which is further arranged in a radially offset manner from the axis of rotation of the shaft 214 so that the axis of rotation of the shaft 214 does not pass through the centre of the ball bearing 242. This is achieved by ensuring that the diameter of the ball bearing 242 is less than the diameter of the chamber of the tubular bearing housing 240 and that the end of the shaft 214 is convex in shape in order to urge the ball bearing 242 towards the wall 244 of the chamber 243 of the tubular bearing housing 240 when the shaft is biased towards the sleeve 218.

In operation of the hammer drill, the shaft 214 is urged by the cam upwards towards the sleeve 218, sandwiching the ball bearing 242 between the end of the shaft 214 and the sleeve and urging the ball bearing 242 against the inner wall 244 of the chamber 243 of the ball bearing housing 240 due to the convex shape of the end of the shaft 214. As torque is transferred from the driving gear 168 via the overload clutch to the bevel gear 158, the bearing housing 240 mounted to the shaft 160 rotates relative to the end of the shaft 214, as a result of which the ball bearing 242 rotates in a generally circular path around the wall 244 of the chamber 243 of the ball bearing housing 240 and the convex end of the shaft 214, thus reducing wear at the end of the shaft 214.

Low Wear Intermediate Shaft Bearing

Referring to FIG. 21, a side cross-sectional view of an alternative hammer drive mechanism and spindle drive mechanism of a hammer drill.

The hammer has a spindle 246 which is mounted for rotation within the hammer housing 4 as is conventional. Within the rear of the spindle 246 is slideably located a hollow piston 248 as is conventional. The hollow piston 248 is reciprocated within the spindle 246 by a hammer drive arrangement. A ram 250 follows the reciprocation of the piston 248 in the usual way due to successive under-pressures and over-pressures in an air cushion within the spindle 246 between the piston 248 and the ram 250. The reciprocation of the ram 250 causes the ram to repeatedly impact a beatpiece 252 which itself repeatedly impacts a tool or bit (not shown). The tool or bit is releasably secured to the hammer by a tool holder of conventional design, such as an SDS-Plus type tool holder, which enables the tool or bit to reciprocate within the tool holder to transfer the forward impact of the beatpiece 252 to a surface to be worked (such as a concrete block). The tool holder also transmits rotary drive from the spindle 246 to the tool or bit secured within it.

The hammer is driven by a motor (not shown), which has a pinion (not shown) which rotatingly drives an intermediate shaft 254 via a drive gear 256. The intermediate shaft 254 is mounted for rotation within the hammer housing 4, parallel to the hammer spindle 246 by means of a rearward bearing 258 (described in more detail below) and a forward bearing 260 of standard design. A spring 262 urges the intermediate shaft 254 rearwardly and is used to damp any reciprocatory motion which is transmitted to the intermediate shaft 254 via the wobble plate hammer drive arrangement described below. The intermediate shaft 254 has a driving gear (not shown) either integrally formed on it or press fitted onto it so that the driving gear rotates with the intermediate shaft 254. Thus, whenever power is supplied to the motor the driving gear rotates along with the intermediate shaft 254.

The hammer drive arrangement comprises a hammer drive sleeve 264 which is rotatably mounted on the intermediate shaft 254 and which has a wobble plate track 266 formed around it at an angle to the axis of the intermediate shaft 254. A wobble plate ring 268 from which extends a wobble pin 270 is mounted for rotation around the wobble track 266 via ball bearings 272 in the usual way. The end of the wobble pin 270 remote from the wobble ring 268 is mounted through an aperture in a trunnion 274 which trunnion is pivotally mounted to the rear end of the hollow piston 248 via two apertured arms 276. Thus, when the hammer drive sleeve 264 is rotatably driven about the intermediate shaft 254 the wobble plate drive reciprocatingly drives the hollow piston 248 in a conventional manner. The hammer drive sleeve 264 has a set of driven splines (not shown) provided at the forward end of the sleeve 264. The driven splines are selectively engageable with the intermediate shaft driving gear 50 via a mode change mechanism (not shown), the operation of which is not relevant to an understanding of the present invention and which will therefore not be described in further detail herein. When the intermediate shaft 254 is rotatably driven by the motor pinion and the mode change mechanism engages the driving splines of the hammer drive sleeve 264, the driving gear rotatably drives the hammer drive sleeve 264, the piston 248 is reciprocatingly driven by the wobble plate drive and a tool or bit mounted in the tool holder is repeatedly impacted by the beatpiece 252 via the action of the ram 250.

The spindle drive member comprises a spindle drive sleeve (not shown) which is mounted for rotation about the intermediate shaft **254**. The spindle drive sleeve comprises a set of driving teeth at its forward end which are permanently in engagement with the teeth of a spindle drive gear **278**. The spindle drive gear **278** is mounted non-rotatably on the spindle **246** via a drive ring which has a set of teeth provided on its internal circumferential surface which are permanently engaged with a set of drive teeth (not shown) provided on the outer cylindrical surface of the spindle **246**. Thus, when the spindle drive sleeve is rotatably driven the spindle **246** is rotatably driven and this rotary drive is transferred to a tool or bit via the tool holder. The drive sleeve has a driven gear located at its rearward end which can be selectively driven by the intermediate shaft driving gear via the mode change mechanism.

The rear end of the intermediate shaft **254** has a convex surface **280**, and the rear bearing **258** of the intermediate shaft **254** comprises a tubular bearing housing **282** foring a chamber of circular cross section for receiving the convex rear end **280** of the intermediate shaft **254**. A ball bearing **284** is received in the chamber of the bearing housing **282** and is radially offset from the axis of rotation of the intermediate shaft **254** such that the axis of rotation of the intermediate shaft does not pass through the centre of the ball bearing **284**. This is achieved by ensuring that the diameter of the ball bearing **284** is less than that of the chamber of the bearing housing **282**. The ball bearing **284** is biased into engagement with the end **280** of the intermediate shaft by means of the spring **2262**, which biases the intermediate shaft **254** rearwardly.

As a result of the bearing arrangement provided at the rear end of the intermediate shaft **254**, construction of the hammer drill is simplified and made more compact, as a result of which its cost of manufacture is reduced, and wear at the end of the intermediate shaft **254** is reduced.

Rear Handle

Referring to FIGS. **22** to **32**, a hammer drill **288** of a further embodiment of the invention has a main housing **290** supporting a chuck **292** for receiving a drill bit (not shown), and a rear handle **294** moveably mounted to the main housing **290** in a manner which will be described in greater detail below. The handle **294** is formed from a first handle part **296** and a second handle part **298**, which have respective mating profiles **300**, **302** to define a chamber containing components **304** actuated by trigger **306** on the handle **294** to control the supply of electrical power to a motor (not shown) located in the main housing **290**.

The mating profile **302** of the second handle part **298** has a larger radius of curvature (Arrow R**1** in FIG. **38**), when in an unstressed state, than the corresponding parts of the mating profile **300** of the first handle part **296** (Arrow R**2** in FIG. **38**), such that when the second handle part **298** is fixed to the first handle part **296** such that the first and second mating surfaces **300**, **302** engage each other to close the chamber enclosed by the first and second handle parts **296**, **298**, the second handle part **298** is placed under bending stress. The bending stress is applied over substantially all of the second handle part **298**, as a result of which vibrations transmitted from the main housing **290** to the handle **294** do not cause significant vibration of the second handle part **298**. However, in an alternative embodiment, the bending stress can be generated by making the mating profile **302** of the second handle part **298** with a smaller radius of curvature (Arrow R**1**), when in an unstressed state than the corresponding parts of the mating profile **300** of the first handle part **296** (Arrow R**2**) as shown in FIG. **39**.

The handle **294** is mounted to the main housing **290** by means of an upper mounting assembly **308**, which enables the upper part of the handle **294** to slide relative to the upper part of the main housing **290**, and a lower mounting assembly **310**, which enables pivoting movement and limited linear movement of the lower part of the handle **294** relative to the lower part of the main housing **290**. The gap between the upper part of the main housing **290** and the upper part of the handle **294** is closed by means of a compressible bellows **312**, which will be described in greater detail below.

Referring in detail to FIGS. **22** to **24**, the main housing **290** contains a motor and hammer mechanism which will be familiar to persons skilled in the art and which will not be described in greater detail herein. The main housing **290** is formed from three clam shells **314**, **316**, **318**, which are screwed together. Two clam shells **314**, **316** form the majority of the housing **290**, and are connected together along a generally vertical plane **320**. The third clam shell **318** is connected to the underside of the other two clam shells **314**, **316** at a generally horizontal plane **322** to allow easy access to the underside of the motor.

The upper mounting assembly **308** has a rigid metal bar **324** connected to and extending from the rear part of the upper part of the main housing **290**. The free end of the metal bar **324** extends into the upper part of the main housing **290**, and is provided with a stop **326** which limits the extent to which the upper section of the handle **294** can move away from the main housing **290**. The free end of the metal bar **324** is received within an elongate recess **328** formed in the upper section of the handle **294** so that the handle **294** can slide along the metal bar **324** towards and away from the main housing **290**. A small gap is provided between the top surface of the metal bar **324** and the upper side of the elongate recess **328** within which it slides, and a small gap is formed between the bottom surface of the metal bar **324** and the lower side of the elongate recess **328**. This allows sliding of the upper part of the handle **294** relative to the housing **290** while pivoting of the lower part of the handle **294** relative to the lower part of the main housing **290** occurs. A compression spring **330** biases the upper part of the handle **294** away from the main housing **290** towards engagement with the end stop **326** on the metal bar **324**, and absorbs vibrations along the direction of the rotational axis of the spindle of the hammer drill **288**.

Referring to FIGS. **30** to **32**, a vibration damper **332** for damping vibrations in a horizontal direction at right angles to the longitudinal axis of the spindle of the hammer drill **288** (i.e. in the direction of arrow Z in FIG. **22**) is mounted to the upper part of the handle **294** and is slidably mounted on the metal bar **324**. The vibration damper **332** has a body portion **334** of hard plastics material defining a hoop **336** slidably mounted around the metal bar **324**, a sliding inner side wall **338** of hard plastics material extending along each side of the metal bar **324**, and outer lugs **340** which are attached to respective side walls of the upper part of the first handle part **296**. Each of the lugs **340** is connected to an outer side wall **342** of hard plastics material which extends along part of the length of the metal bar **324** such that the outer side walls **342** can pivot or otherwise move relative to the sliding inner side walls **338**. A wedge shaped compressible member **344** of resilient material is sandwiched between the inner side walls **338** and the outer side walls **342**, such that compression or expansion of the wedge shaped compressible member **344** occurs as the metal bar **324** moves in the direction of the arrow Z in FIG. **22** relative to the upper part of the handle **290**.

It can also be seen that a further piece **346** of compressible material is provided on an end wall of the outer lugs **340** to damp transmission of vibrations from the end stop **326** on the metal bar **324** to the lugs **340**, and therefore to the handle **290**, when the vibration damper **332** is in engagement with the end stop **326** at the outermost position of the handle **294** relative to the main body **290**. Vibrations can also be damped by means of a spring (not shown), instead of or in addition to the wedged shaped compressible members **344**, located between the inner and outer side walls **338**, **342**.

FIGS. **36** and **37** show an alternative embodiment of vibration damping mechanism for use in the upper part of the handle **294** of the hammer drill **288** of FIG. **22**. A vibration damper **348** is slidably mounted to the metal bar **324** and has inner side walls **350** and outer side walls **352** which can slide relative to each other as movement of the metal bar **324** relative to the first handle part **296** occurs in the direction of arrow Z in FIG. **36**. A block **354** of compressible resilient material is located between the inner and outer side walls **350**, **352** to dampen vibrations arising as a result of relative movement in the direction of arrow Z. The inner and outer side walls **350**, **352** can slide relative to each other along two orthogonal directions (i.e. parallel to the direction of arrow Z, and parallel to the longitudinal axis of the metal bar **324**), to accommodate rotation of the metal bar **324** relative to the handle **294**. Resilient members **346** are provided on the end stop **326** to damp vibrations transmitted from the metal bar **324** to the handle **294** when the vibration damper **348** engages the end stop **326**. A further vibration damper **348** (not shown) identical to that shown in FIG. **36** is provided on the opposite side of the metal bar **324**.

As shown in FIGS. **27** to **29**, the bellows **312** joining the upper part of the handle **294** to the upper part of the main housing **290** is formed from durable plastics material and has a first mounting part **356** for mounting to the handle **294**, and a second mounting part **358** for mounting to the housing **290**. The first and second mounting parts **356**, **358** are connected by a compressible part **360** formed from pleated plastics material, and is provided with a compressible elastomeric member **362** between one or more pairs of adjacent pleats. in this way, as the upper part of the handle **294** is pushed towards the upper part of the main housing **290** towards its position of closest proximity to the main housing **290**, the vibrations transmitted from the hard plastic second mounting part **358** attached to the housing **290** to the hard plastic first mounting part **356** mounted to the handle **294** are damped as the first and second mounting parts **356**, **358** move closer together.

An alternative design of an arrangement for damping vibrations of the handle **294** in the Z direction is shown in FIGS. **33** to **35**. Referring firstly to FIG. **35**, a vibration damper **364** is located on each side of the metal bar **324** between the metal bar **324** and an internal surface of the first handle part **296**, and has a sliding part **366** of durable plastics material slidably mounted to the metal bar **324**, and outer lugs **368** rigidly mounted to the first handle part **296**. Outer walls **370** are rigidly fixed to the lugs **368** by means of screws **372** in such a way that the outer walls **370** and lugs **368** can pivot together relative to the sliding parts **366**, and a wedged-shaped member **374** of compressible resilient material is sandwiched between each sliding part **366** and the corresponding outer wall **370**. A compression spring **376** mounted to the housing **290** biases each outer wall **370** and the corresponding lug **368** towards the end stop **326** at the end of the metal bar **324**.

Twisting of the handle **294** about a vertical axis generally parallel to the longitudinal axis of the handle **294** causes compression of the elastomeric member **374** on one side of the metal bar **324** and expansion of the elastomeric member **374** on the other side. In this way, torsional vibrations about the vertical axis are damped.

Referring to FIGS. **24** to **26**, the lower mounting assembly **310** connecting the lower part of the handle **294** to the lower part of the main housing **290** will now be described.

The third clam shell **318** has a pair of inner walls **380**, each of which is provided with a generally circular aperture **382**, the circular apertures **382** being aligned with each other along a horizontal axis. The lower part of the handle **294** surrounds the circular apertures **382**, and a pivot pin **384** extends between the inner side walls of the lower section of the handle **294** across the width of the lower section of the handle and passes through the two circular apertures **382** to define a pivot axis for pivoting movement of the lower part of the handle **294** relative to the lower part of the housing **290**, the pivot axis being generally parallel to the central axes **386** of the circular apertures **382**.

A resilient member **388** is located between the inner periphery of each aperture **382** and the pivot pin **384**, the resilient member **388** having a generally circular outer periphery to fit the inner periphery of the aperture **382** and an aperture **390** for receiving the pivot pin **384** and which is generally offset from the centre of the resilient member. The position of the pivot pin **384** when inserted through the aperture **390** in the resilient member **388** can be adjusted by applying a force to the lower part of the handle **294** to push the lower part of the handle **294** towards the main housing **290**, to cause compression of the resilient material of the resilient member **388** forwards of the pivot pin **384**, and expansion of the resilient material behind the pivot pin **384**. The pivot pin **384** can freely rotate within the aperture **390** in the resilient member **388**.

Referring to FIG. **25**, when no force is applied to the handle **294**, the pivot pin **384** is biased by the resilient material of the resilient members **388** to the position shown in FIG. **25** such that the longitudinal axis of the pivot pin **384** is located to the rear of the longitudinal axes **386** of the two apertures **362**. When the hammer drill is in operation, however, a force is applied to the handle **294**, which urges the lower part of the handle **294** towards the main housing **290**. This causes the pivot pin **384** to move forwards relative to the apertures **362**, and the longitudinal axis of the pin **384** moves towards the longitudinal axes **386** of the apertures **362**. The spring force of the resilient material is chosen such that when the operator applies a typical force to the handle **294** during operation of the hammer drill, the longitudinal axis of the pin **384** is aligned with or located close to the longitudinal axes **386** of the apertures **362** to maximise the vibration damping effect of the resilient members **388**.

During operation of the hammer drill **288**, the operator applies a force on the handle **294** to push the drill bit (not shown) of the drill against a workpiece. Since the major component of the force is applied along the working axis of the drill, i.e. the longitudinal axis of the spindle of the drill, the upper section of the handle **294** slides along the metal bar **324** and compresses the spring **330**, while also causing the pin **384** in the lower part of the handle **294** to move forwards towards the central axes **386** of the apertures **362**, as shown in FIG. **26**. The upper section of the handle **294** moves more than the lower section, as a result of which the handle **294** pivots relative to the main housing **290**. This pivotal movement is accommodated because the pin **384** can pivot in the direction of arrow D shown in FIGS. **25** and **26** relative to the resilient members **388**.

As a result of the operation of the tool, vibrations are generated primarily in the direction of arrow X in FIG. **22**, but are also generated along the two axes orthogonal to the direction of arrow X. The vibrations in the direction of arrow X are predominately absorbed by the upper mounting assembly

308, since it is closer to the axis of travel of the ram, beat piece and cutting tool, the absorption occurring as a result of the metal bar 324 sliding in and out of the elongate recess 328 and compressing and expanding the spring 330. However, vibrations in the direction of arrow X are also absorbed by the resilient members 388 in the lower mounting assembly 310 by movement of the pin 384 sideways in the horizontal direction within the apertures 362. Since more movement in the direction of arrow X occurs at the top of the handle 294, this is accommodated by the pin 384 pivoting in the resilient members 388.

Vibrations in the direction of arrow Y in FIG. 22 are absorbed by the lower mounting 310 arrangement by means of the resilient members 388 being compressed and expanded as the pin 384 moves vertically within the apertures 362. The small gaps between the metal bar 324 and the upper and lower sides of the elongate recess 328 allow for movement of the metal bar 324 in the direction of arrow Y. The vibrations in the direction of arrow Z are absorbed by means of the vibration dampers 332 mounted to both sides of the metal bar 324.

It will be appreciated by persons skilled in the art that the above embodiments have been described by way of example only, and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims.

The invention claimed is:

1. A handle housing for a handle for a power tool, the handle housing comprising:

a first housing part; and

a second housing part adapted to be mounted to the first housing part, said first and second housing parts defining a chamber accommodating one or more motor control components of the power tool;

wherein the first housing part has a first engaging portion, the second housing part has a second engaging portion adapted to engage said first engaging portion, and at least part of said second engaging portion has a larger radius of curvature than the corresponding part of said first engaging portion in an unstressed state, such that when the second housing part is fixed to the first housing part such that the first and second engaging portions engage each other to close the chamber defined by the first and second housing parts, the second housing part is placed under a bending stress which is applied over substantially all of the second housing part.

2. A handle housing for a handle for a power tool, the handle housing comprising:

a first housing part; and

a second housing part adapted to be mounted to the first housing part, said first and second housing parts defining a chamber accommodating one or more motor control components of the power tool;

wherein the first housing part has a first engaging portion, the second housing part has a second engaging portion adapted to engage said first engaging portion, and at least part of said second engaging portion has a smaller radius of curvature than the corresponding part of said first engaging portion in an unstressed state, such that when the second housing part is fixed to the first housing part such that the first and second engaging portions engage each other to close the chamber defined by the first and second housing parts, the second housing part is placed under a bending stress which is applied over substantially all of the second housing part.

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